THE SCIENTIFIC BASIS OF PHYSICAL EDUCATION

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FOREWORD

THERE is to-day a great ferment in the field of physical education. The very breadth of the subject allows of its study from many angles and as many different conceptions of what constitutes physical education and the best methods of its promotion.

It will, I think, be generally accepted that the report of the British Medical Association on physical education published in 1935 is the only attempt to survey this subject in a comprehensive manner, and that the report has focused attention on the most important principles which must underlie any successful effort to remedy the neglect of this aspect of education in our national life.

No single principle is more strongly insisted upon in this report, or is more generally accepted without disagreement, than that which recognizes the intimate association between physical education and the science of medicine, and the need for the closest co-operation between the doctor and the physical trainer.

The General Medical Council in its memorandum on medical education rightly insists on the teaching of medical science from the preventive aspect, yet the amount of attention given to this exhortation will, in the opinion of not a few, amount to little more than lip service so long as our great health services remain outside the purview of the medical student.

How then shall the doctor whose interest in this subject is awakened obtain the information he seeks?

Dr. Griffin in this book has set out a comprehensive and up-to-date summary of the medical and scientific knowledge at present available. The long bibliography at the end of the book speaks for itself, but in addition the reader will find practical suggestions of both value and interest.

The consideration of the subject from the psychological aspect will present to many a new field of thought, and the initial attempt to designate physical types in the same race as a basis for determining the most suitable form of physical education points the way to further research.

The establishment of a national training college will

provide the means, at present almost entirely lacking, for scientific study of these and similar problems. What the British Medical Association has done over a wide field has now been amplified in the medical and scientific aspect by Dr. Griffin in this book.

KAYE LE FLÉMING

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I

PRACTICE AND RESEARCH

PHYSICAL exercise involves many activities, each of which is brought about by complex mechanisms—anatomical, physiological, and psychological. Neglect of these mechanisms has in the past vitiated many apparently promising lines of physical training; it has injured some persons physically by over-development or straining; it has failed in its purpose of enhancing the vitality of some by inattention to under-development; and so it has deprived the community of the benefits which would otherwise have accrued from wisely planned and correctly executed physical education. It is therefore essential for all medical practitioners, as well as for others interested in this branch of education, to be as fully informed as possible in these respects so that they may be able to give sound advice and to direct such training with the maximum efficiency for the population as a whole as well as for individual cases.

This was fully recognized by Peter Ling at the beginning of last century. Before he set out to devise schemes of physical training for the ordinary citizen and for sick persons, as well as for the army of his time, he made a careful study of all the scientific knowledge (mainly anatomical) then available. Since his day there have been great advances in science, and the task of establishing a basis, even remotely comparable with his, is immensely difficult by reason of the wealth of material available for this purpose. For instance, the physiological and psychological conceptions of to-day are almost entirely new; they are founded now to a very much greater extent on ascertained facts rather than on fancies. Anatomical science has progressed almost beyond estimation, while the dynamics of physical movements are better understood. Each year fresh discoveries widen

knowledge of the functions as well as of the structure of the human body.

In this book an attempt is made to survey the present position so that the present urge towards healthier living may result in the planning of an advance on scientific lines. No special theory of training is advocated. Holders of conflicting views will find in the following pages evidence in support of some contentions and in rebuttal of others, as well as an implied appeal for more precise thinking and exercises of less conjectural value.

COMPLEXITY OF THE PROBLEM

Swimming, running, gymnastic exercises, and other such muscular activities involve questions of muscular structure and the local blood- and nerve-supply; of the degree of efficiency of the heart and lungs; of physical and chemical changes in the body tissues; of nerve reflexes; and of psychological stimuli and repressions. These vary in different persons, and at different times in the same person, but it is still possible to draw some general practical conclusions as well as to indicate the causes and treatment of individual variations. Laws and exceptions can be defined. It is possible to indicate how to set about the task of discovering the most suitable physical activities for different classes of the population as well as for various physical types of individual or for those who are handicapped in some way—a great saving of time and labour, as well as a great boon for the persons concerned.

Physiological researches connected with the heart and lungs have conferred upon mountain climbers greater possibilities than were previously guessed; they can also be applied to the endowment of the city worker and agricultural labourer with powers of living more fully, healthily, and happily. The science of orthopaedics, discussed practically by Hippocrates as regards its application to the improvement of the general health by exercises as well as

to the correction of physical deformities by apparatus, had been forgotten by the intervening centuries until in these latter years it underwent a renaissance rendering it more potent than ever to confer beauty, grace, and power on the human body. Psychological studies have shown that it is possible to minister most successfully to a mind diseased, the methods being not only those of psychological treatment but also of physical education. They have revealed that there are means of discovering which forms of physical recreation are best suited to different cases; in conjunction with observations of physical characteristics they afford a system of recreational guidance.

Some have yet to realize that a simple symptom such as shortness of breath on exertion may require to be treated by exercise rather than by rest, may be due to underdevelopment rather than to strain or to malnutrition, or may originate from psychological conditions. Diagnosis is immensely easier to-day in these respects than it was only a few years ago, and rule-of-thumb decisions are no longer permissible. Malnutrition may occur when the food intake is more than adequate, and athletic activity bring about its cure. Breathing exercises when properly performed may be of very great value, even to an athlete. The reflex mechanisms governing muscular activities and development must be understood by those who plan schemes of muscular exercises if the results are to be good. These and other complexities associated with physical training will receive attention later on; they are mentioned here to illustrate the point that the reign of blind empiricism (prescribing physical training about the effects of which little is known for physical bodies even less well understood) is nearly over.

Consequently, openings for research are very many for the teacher in the gymnasium or the leader in the playing-field as well as for the medical practitioner in his consulting-room and the laboratory investigator. It is high time that some form of team work for all these was established, so

that greater speed in progress might result. Definite standards of fitness, based on scientific lines and generally applicable, must be framed, so that comparative statistical studies may advance knowledge. The existence of recognizable constitutional and athletic types of physical build has long been proclaimed, but more research is necessary in order to define practically useful systems of classification which will win general acceptance. In addition to such great fields for original work there are many clinical observations to be made and recorded in respect of physical, physiological, psychological, and remedial work. Further reference to these will be made in the following pages.

This fully justifies the appeal made to-day to the medical profession to take a very active part in the campaign for better physical education; their services are very urgently needed. A new field is opening for medical practitioners. They are asked to add to their duties of curing and preventing disease the even more important one of promoting health, and the lines on which they can work are already fairly clear. The tendency to specialism in this subject is obvious, but there is an equal need of the active assistance of those who will take into their purview in general practice the work of actively promoting scientific lines of physical training by closely associating themselves with the local possibilities as they steadily develop. Quackery is just as rampant in this sphere as elsewhere, and can only be combated by better education of the general public, a task which is essentially one for the medical practitioner and the physical educationist. The present book actually evolved from a series of lecture notes for medical practitioners and laymen on physical education. It is hoped that it will enable many teachers to devise lectures and schemes of instruction.

Finally, physical exercises bring sometimes special injuries into the purview of the medical practitioner. Heald's book, *Injuries and Sport*, covers this problem so well that very little remains to be recorded in the present survey.

The scientific basis of his instructions and advice is dealt with to some extent in his chapters, and I have been enabled thus to confine myself to the functioning of healthy structures. His insistence on repair being a repetition of development is noteworthy. His methods of diagnosis of injury are comprehensive, ingenious, and very practical. His appendix on recreational therapy should not be overlooked by those who are considering developmental rather than reparative activities.

II

MUSCLE STRUCTURE AND ACTION

THREE kinds of muscles are concerned in physical exercise. The voluntary muscles, numbering over 400 and composing as a rule about one-half of the body weight, shorten more than a third of their length in contraction, and are composed of striated fibres. The involuntary muscles, so called because they are usually uncontrolled by the conscious will, are nevertheless responsive to stimuli arising from the sympathetic nervous system and the 'subconscious' or 'unconscious' part of the personality, and are composed of unstriated fibres. The heart-muscle is made up of striated fibres, the contraction of which is brought about by stimuli originating in the cardiac centres in the brain. While there is no need to reiterate the simple anatomical and physiological details to be found in ordinary text-books, reference must be made to certain points which have an important bearing on certain aspects of physical training.

In giving instruction to classes I have found it convenient to suggest the structural analogy of the orange segment. It is thus possible to indicate how each spindle-shaped striated fibre of voluntary muscle consists of a mass of colloidal material arranged as a longitudinally placed group of fibrils (sarcostyles), which are surrounded by sarcoplasm and enclosed in a connective tissue sheath. These fibres are bound together in a connective tissue sheath to form little bundles (fasciculi), which are themselves grouped in larger bundles, the whole being enclosed by a sheath of white connective tissue, the fibres of which converge and merge at the ends of the muscle to form the tendons. This connective tissue structure is of importance in considering such conditions as fibrositis.

Each muscle fibre has a thin homogeneous elastic tissue coat (sarcolemma), and is bathed in lymph; consequently, metabolic changes in the body modify the chemical and physical composition of the lymph and may have a direct action on the muscle fibres. Each fibre receives a motor-nerve thread which penetrates the sarcolemma and terminates in an end-plate composed of branching nerve-endings embedded in a granular substance. Between the muscle-fibres in the connective tissue are scattered the sensory nerve 'muscle-spindles'; these are compressed by the contraction of the muscle, causing sensory impulses to travel to the central nervous system. Very thin walled arterioles and venules lie in the connective tissue between the fibres, and thus a free exchange is possible of their contents with the muscle tissue, a similar arrangement occurring in the case of the lymphatic vessels.

The redder skeletal muscles contain a pigment which is possibly identical with the haemoglobin of the red blood corpuscles, and are capable of long-continued or sustained contractions. The paler muscles are made up of less granular and more distinctly cross-striated fibres; they are more irritable and contract more rapidly, but cannot maintain their contraction so long. Flabby and paralysed muscles are paler than normal, and it would seem that this pigment may have some function in facilitating the oxygen storage in muscle tissue, and in promoting muscular activity—a point which deserves further investigation from the standpoint of therapeutic possibilities in wasting diseases and in the weakness attending convalescence. The diaphragm muscle lying between the chest and abdomen is much stronger than the others; it can work longer, and resist better the effects of fatigue and starvation.

MUSCLE CHEMISTRY

It is generally believed that the contractile elements of the muscle-fibre are the sarcostyles which consist of water-

swollen myosin; two other proteids have been distinguished in skeletal muscle, namely myogen in the sarcoplasm, and a less clearly designated one in the muscle stroma framework within the individual fibres. The sarcostyles consist of regularly alternating isotropic and longer anisotropic segments which latter are the essential contractile elements, being composed of myosin. Water makes up 75 per cent. of the muscle mass, and glycogen 0·4 to 0·9 per cent. of its weight varying according to the degree of activity which has been exercised. Fat is found in the connective tissue, and to a less extent in the fibres.

By extraction with boiling water, muscle tissue yields creatine, creatinine, and urea, &c., which are nitrogenous, and lactic acid and inosite (muscle sugar). The chemical changes in rest and activity are brought about by enzymes of various kinds. F. S. Lee and others (1909 and 1916) have shown that the protein sulphur and the glycogen content are correlated with muscular respiration and energy. H. C. Bradley (1922) associates muscular atrophy with liquefactive action of the muscle proteins by enzymes. A. V. Hill (1923, &c.) has shown that muscular activity leads to disappearance of glycogen and the appearance in the muscle of lactic acid; preformed carbonic acid is driven off; heat is produced; and the hydrogen-ion concentration rises.

In the *Physiology of Muscular Activity* (1933) E. C. Schneider surveys the more recent views held about the chemistry attending muscular contraction. He considers it definitely proved that the initial energy is derived from the splitting of phosphocreatine (phosphagen or creatine phosphate) into creatine and phosphoric acid, and that immediately afterwards the phosphocreatine is reformed by the energy derived from the splitting up of a compound of adenylic acid and pyrophosphoric acid (adenosinetriphosphate) into phosphoric acid, ammonia, and inosinic acid (E. Lundsgaard, 1930). Next, glycogen breaks down, one of its resultants—lactic acid—supplying the energy neces-

sary for the resynthesis of the adenosinetriphosphate, an intermediate product in this step being the formation of hexose-diphosphate (Samson Wright's *Applied Physiology*, pp. 500 and 570). Finally, glycogen is reformed by the oxidation of the lactic acid (H. E. Himwich and others, 1923, 1927, 1929, and 1932). The old view that lactic acid was essential for the production of tension in muscles can no longer be held (Lundsgaard).

During activity muscles become acid in reaction owing to the appearance of lactic acid, and exhaustion occurs when oxidation of this does not follow or the lactic acid is removed by the blood-stream. Such removal, however, would obviously impair the storing up of fresh energy in the muscle, and Hill has shown that during the resting period after contraction only one-fifth is thus lost if adequate oxygen is present. This fifth is normally broken down into water and carbon dioxide, but in fatigue conditions it accumulates in the blood and the tissues. The maximum lactic acid content is found about ten minutes after an athletic performance (Schenk and Marburg, quoted in the *Physiology of Exercise* by F. A. Schmidt and C. B. Sputh, 1931), and its suitable disposal is one of the essential points in physical training. (Cori thought that some might be reconverted by the liver, the steps being: muscle glycogen → blood lactic acid → liver glycogen → blood glucose → muscle glycogen.) The varying capacity of different persons to deal with this determines athletic prowess of different kinds; innate powers can be enhanced thus. The services of the medical practitioner as well as of the scientist can be most effective, but further research is still required from both. Berner and others (1926) have brought forward evidence that variations in muscle temperature may be a factor in developing the power to deal with lactic acid, and that such temperature is raised when the bodily metabolism is high, as in very vigorous work, or when the surrounding air is warm. This last point is of practical interest to trainers of athletes, but

the general optimum temperature for various kinds of exercises has yet to be determined. The incidence of 'second wind' depends consequently to some extent on the external atmosphere, as Berner and his colleagues showed. They pointed out that this incidence could be postponed by cold draughts, and accelerated by warm clothing, so it is by no means scientifically indicated that the nudist trend in modern athletics is altogether physiologically desirable.

MECHANISM OF MUSCULAR ACTION

Muscle-fibres are 'insulated' from their neighbours, and the action of each is conditioned by its own nerve-fibre as well as by the physical and chemical considerations already indicated. They resemble gun cartridges in that they 'go off' at full strength in answer to a stimulation, or not at all if the stimulation is too small. When a muscle contracts more completely, more of its fibres have been thrown into action; no individual fibre is working harder than before. The nerve impulses reaching muscles are not single, but multiple; hence reflex and voluntary contractions alike are tetanic in character; they respond to a succession of closely spaced stimuli.

When a muscle remains contracted for some time the same fibres are not operating continuously. Stiles (1923) suggests the following illustration: 'It is reported that when a gang of East Indian coolies are carrying a piano above their heads a number of substitutes trot beside the group and from time to time replace its members. Each man thus released continues with the procession, and presently takes his turn again.' It is obvious that in conditions calling for prolonged contraction fatigue will occur earlier than when there is some intermittence. A practical deduction from this is the need of providing variations when planning a training programme. This secures resting periods for muscles or groups of muscles; the value of this is still further enhanced if flexion and extension exercises follow each

other. Hill has remarked, however, that a muscle has a certain degree of inherent power of adapting itself to the conditions it meets. This power is increased by training on right lines, but is diminished by prolonged straining efforts which, consequently, may have the opposite result to that which is desired. This point is too often overlooked by professional and amateur athletic trainers. Galloway (1937) remarks that violent stretching of muscles and ligaments may temporarily make a joint more mobile but only by weakening all these structures. 'It is little short of criminal to employ violent stretching exercises. Momentum should never be employed to stretch muscles or ligaments. Strengthen the weak muscles by rhythmic exercise, and the contracted antagonists will attain their correct length and the joint its mobility without risk of damage.'

The old idea that the muscle was comparable with a steam-engine, burning up fuel, is not altogether appropriate, since the oxidation processes follow rather than precede contraction. A better simile is afforded by the electric accumulator or secondary battery, discharges of energy from which are caused by chemical action within itself, and succeeded by the restoration of the energy by reverse chemical changes, as has previously been indicated. Heat is evolved in the muscles during contraction, mainly owing to the breaking down of glycogen into lactic acid, which is neutralized by buffer substances in the muscle—particularly by the muscle protein—thus evolving more heat, the whole being termed the 'initial heat' which is liberated in the absence of oxygen. In the presence of oxygen some of the lactic acid is then oxidized, liberating heat ('delayed' or 'oxidative' heat) which is partly used to bring about the rebuilding of glycogen.

It should also be noted that the viscosity of muscle, which differs in different persons, affects muscular action; greater degrees resisting the contraction, and consequently the

speed of movement. Schneider points out that there is an optimum speed for muscle action, and army authorities found originally that an average of 120 steps per minute was the optimum rate for marching. This mechanism which is inherent in the muscle-fibres themselves prevents too rapid movement. The greatest speed which can be maintained for a given time is determined by the amount of energy expended and by the degree of fatigue produced.

This has a practical bearing upon athletic training and prowess, since viscosity varies in different persons. Best and Partridge (1930) found by study of Olympic runners that one of the men who equalled the world's record for the indoor sixty-yard dash had the smallest degree of viscosity. Women runners have a relatively low viscosity, but the proportion of body-weight which they can exert as propelling force is considerably less than that of men, a counterbalancing factor of great importance. Possible sprinters can be detected by viscosity measurements, but other physiological and psychological considerations are also involved unfortunately. No excess of straining work will improve some subjects, obviously, and in this connexion it must be remembered that ruptured muscle-fibres cannot regenerate, nor do new ones appear, and that muscles may be actually weakened by such practices.

Reference may also be made here to the measurement of muscle tonus. Some tonic longitudinal pull is exerted by the bundles of fibres in a muscle even at rest, and this is lessened in some cases even when the tendon reflexes are increased (as in some forms of neurasthenia). A way of estimating it has been described by Yandell Henderson in America, and an improved method by J. D. Olav Kerr and L. D. W. Scott (1936) in England. These latter investigators found that many cases of neuro-circulatory weakness, premature exhaustion during exercise, and disordered action of the heart were apparently due to depressed muscle tonus, resulting in defective venous return

of the blood to the heart from the muscles. This depression was attributable in some cases to previous or concurrent infections, and its estimation by the medical practitioner would seem to afford a useful way of determining when a person who had been ill could resume active physical training, psychological considerations being thus relegated to a rightly secondary significance. Here, again, research on a much larger scale by the clinician is indicated in view of the practical value to be attached to knowing when the person is again muscularly fit, and does not only think that he is so.

III

MUSCLE MECHANICS AND EFFECTS

MUCH research has already been conducted in various countries as regards the mechanical aspects of muscular contraction, and only a brief reference to some of the points can be made here. It has been estimated that the human body at rest uses up from 210 to 300 cubic centimetres of oxygen each minute, and for the maintenance of life alone there is required each minute 1·28 calories of energy. (The calory is the term given to the amount of heat required to raise 1 kilogram, or 2 lb. 3 oz. of water, 1 degree Centigrade.) When 35·2 ounces by volume of oxygen are used in 'burning up' glycogen, 5·1 calories are produced. The oxidation in the body of 15 grains of carbohydrate (sugar, starch, &c.) yields about 4 calories; the burning of the same weight of fat yields about 9 calories, while that of the same weight of protein produces between 4 and 5 calories. From these values the amount of energy in a man's diet can be estimated. These calculations apply to a person lying down; assumption of the sitting or stand-posture, involving muscular activities, requires the availability of more energy, in the latter case about 9 per cent. more.

The energy used during horizontal walking has been calculated by F. G. Benedict and H. Murschauser (1915), while the former author in association with H. S. Parmenter has worked out the comparable amounts for ascending stairs (1928) and the effects on the human skin temperature of muscular activity, exposure to cold and draughts, subjects which have also been studied in great detail by A. V. Hill and L. Hill (1922). Benedict and Murschauser published experimental evidence with regard to the effect of speed on the physiological cost of walking. The opti-

mum rate in one case was 98 yards a minute, and slower or faster speeds increased the using up of oxygen and the expenditure of calories. They showed further that the mere action of raising the body involved the expenditure of just under a fifth of the total energy concerned, and that an important factor was the type of step employed. In running the body is raised higher than in walking; the length of step is greater in very rapid walking than in running. E. Atzler and R. Herbst (1927) found in one subject that the most favourable rate of walking was 87 steps a minute.

Benedict and Parmenter (1928) have worked out a simple plan for determining the total energy cost involved in walking on a level; the body weight in pounds is multiplied by the distance in miles, and the result by 0·56 large calories (0·00056 ordinary calories). They further showed that the optimum rate for women was 2·24 miles an hour, and that sauntering led to greater expenditure of energy. Arm-swinging and laborious gaits still further increase this expenditure.

Benedict and Murschauser (1915) reach the following practical conclusion. Minimizing the raising of the body is a desideratum. Athletes and others interested in the work of long-distance walking should aim at diminution of this and of arm-swinging, neither of which helps in the main objective. This is an example of practical conclusions reached by direct physiological investigation; they contradict some of the teaching of some schools of to-day, and should therefore be known to medical advisers interested in physical education.

Benedict and Parmenter (1928) report that for women the average total cost of climbing stairs is 0·012 calories for each kilogram (2 lb. 3 oz.) raised 1 metre (39·37 in.). To ascend the average staircase of 15 steps in each flight, representing a vertical climb of about 10 feet, demands an expenditure of energy representing rather more than

2 calories by a person weighing just over 9 stone. Thus an average person uses up as much energy in walking up a flight of 15 stairs each 7 inches high as he would do in walking on a level fifteen times the distance represented by the vertical height of such a staircase. Descent of the staircase requires one-third of this energy.

A. Fleisch (1926) worked out the metabolic requirements in marching. As Schneider points out, it is now possible to prescribe an exact dose of stair-climbing considered desirable for weight reduction, or not to be exceeded in heart disease, provided that it is remembered that the average adult expends 0·046 to 0·051 calories in walking 1 metre on the level.

H. Lupton (1923) analysed the effects of speed on the mechanical efficiency of human muscular movement, and showed that there was a certain optimum rate for each person at which the cost of the exertion was reduced to the minimum. In one case the optimum time was 100 seconds for 78 steps, when the excess of oxygen consumption amounted to about 1,450 cubic centimetres, the duration of each step taken being 1·3 seconds. In prescribing exercises for patients it would obviously be possible to be exact, with very distinct benefit to some who would otherwise be exposed to the risks of a method of trial and error—another indication of the practical value of this work.

MECHANICAL EFFICIENCY OF THE BODY

An ordinary locomotive wastes about 90 per cent. of its available energy as heat, only 4 per cent. being represented as profitable work. F. G. Benedict and E. P. Cathcart (1913), working on a bicycle ergometer, found that the net efficiency figures were about 20 per cent. for untrained men, 25 per cent. for most trained men, and from 33 to 41 per cent. for very strong athletes. E. Atzler and R. Herbst (1927) estimated the efficiency of walking exercise to be about 33 per cent. The trained man can do a certain per-

formance with less expenditure of fuel and oxygen than can the untrained man; the first has learned how to use his physical powers more thriftily, a matter of physiology as well as of increasing skill in technique as will be shown later. H. Gessler and R. Market (1927) report that at the age of 17 the average efficiency of the human muscle is 15·8 per cent., and that it increases up to the age of 44 when it is ordinarily about 23·5 per cent. In this paragraph is indicated a definite argument for suitable physical training in young adults, who may thus acquire just the extra amount necessary to withstand the onslaught of an attack of pneumonia, for example.

K. Furusawa, A. V. Hill, and J. L. Parkinson (1927) calculated the 'energy' expended in sprinting, by collecting the expired air and determining the 'oxygen debt'—or, as Samson Wright prefers to call it, the 'recovery oxygen'. Various 'efficiencies' thus measured were 36·5, 36·9, and 41·1 per cent. W. O Fenn (1929 and 1930) worked out comparisons in terms of horse-power. He found that running at top speed evoked a mechanical efficiency in the neighbourhood of 22·6, an equivalent of 2·94 horse-power (1 horse-power equals 33,000 foot-pounds a minute, the foot-pound representing 1 pound weight lifted 1 foot vertically). In steady exertion the efficiency increases for a time and then decreases.

The work accomplished by a maximal muscle effort varies inversely with the speed of contraction, being greater at low speeds. Here again there is an optimal rate for muscular contraction, determinable by scientific study, but hitherto neglected unfortunately by some schools of physical training who rely on a 'rhythm' which has no precise periodicity and consequently proves sometimes disappointing in its results as regards the enhancement of physical fitness. As in the case of other empiric doctrines and methods of training, this 'rhythmical' training, which differs vastly in different schools, demands scientific study by the

general medical practitioner, laboratory worker, and the physical education experts conjointly before its full value can be assessed and it be approved otherwise than tentatively. It is significant that the prescribed rate varies from year to year in certain training schools, indicating that there is no established optimum rate. The suggestion has been made that certain obscure though definite nervous disturbances may result owing to ill devised 'rhythmical' exercises.

Net muscular efficiency figures are obtained for purposes of comparison by multiplying the amount of work performed by 100, and dividing this by the result obtained from subtracting the expenditure of energy during a similar resting period from the total expenditure of energy during it. It has been stated that the efficiency figures of men generally are greater than those of women. It is obvious that in both sexes they will be affected by infections and obesity, but much more research is wanted in this respect also as well as in the actual extents to which improvement can be secured by athletic pursuits of various kinds in various types of humanity. At present we are blundering along blindly in a mist of conflicting speculations, and our campaign for national fitness is being impeded by the lack of precise knowledge in this as in other respects.

E. C. Schneider (1933) and others hold that the highest possible maximum for sustained muscular work or effort involves the production of 600 calories of energy per hour; such an expenditure of energy has been maintained by a champion bicycle rider, a long-distance runner, an experienced mountain climber, and a capable swimmer. In the case of a man with an efficiency of 20 per cent., the maximum amount of work is about 0·18 to 0·19 horse-power per minute. W. O. Fenn (1930) calculated that the average man in sprinting worked at the rate of 2·95 horse-power, his rate of energy expenditure being about 13 horse-power at maximum speed, and his net muscular efficiency about 22·7 per cent.

TESTS OF STRENGTH

Many of the older methods of measuring strength are of doubtful value; these include the lifting of weights and tests of the force of hammer blows, all of which require positive effort to be made by the subject. E. G. Martin (1918) of Stanford University has devised a strength test which is probably on better lines, depending on the resistance of the subject to a pull against him, and has recorded dynamometer resistance for various groups of muscles.

There is much less difference between the two sides of the body than is generally imagined, but there is some correlation apparently between strength and body-weight. Martin and Rich (1918) have shown that when two persons of equal weight differ markedly in strength one or more of four factors may be concerned: (1) the actual amount of muscular tissue; (2) a difference in muscular quality; (3) differences in the attachments of muscles—an anatomical question; and (4) questions of muscular innervation and psychology. Well-built men register greater strength generally than do slim men, while heavily built men are stronger than slender men of the same weight. The greatest strength is attained by the average man at the age of 30, after which there is a gradual decline. A number of practical points arise out of these and similar considerations, of which the following may be taken as examples.

When advocating physical education to an audience of young women I have found that emphasis may conveniently be laid on 'health and beauty'; in the case of lads 'health and strength' is the desideratum. In both it is important to make clear how maximum efficiency should be the objective, and that the physical type of each person should be taken into account. In this connexion enough has not yet been made of the typing suggested at the beginning of this century by Kretschmer in Germany and by Bernard

Hollander (1901) in England. Both systems are closely similar. The youth of either sex should not be allowed to incur disappointment by comparing his or her physical progress with that of others of different types.

The medical adviser to a physical training institute must make himself familiar with the broad outlines of these distinctions before he starts to examine, let alone to advise. An apparently poor musculature involving deficiency of physical energy may be due to under-development more than to faulty nutrition; it may also be very good in view of the type of body build and only require that its functioning be improved, or the psychological make-up may be impaired. Thus there are four totally different ways in which correction may be desirable, and the medical adviser must know how to distinguish whether any one or more should receive attention.

This work is sometimes well outside the ability of even the experienced lay physical training instructor, and all are not so experienced as they think they are as regards individual progress, though they may have a deep knowledge of their own particular system of training and its general possibilities. Co-ordination of their work with that of the scientist and the medical practitioner will work apparent miracles in many individual cases. There is no imaginable standard system of training which will meet all requirements, though some exercises seem to be more generally applicable than others, but it is probable that any system would be rendered much more efficient by such team work.

A three minutes' talk to a class of lads on various muscular possibilities will evoke a host of practical questions of very different kinds, but indicating various individual needs most of which can be met immediately. This is a much better plan than giving a lecture for half an hour or more on 'hygiene'. Some questions will be asked openly, but the majority, and the more important ones, will only be

forthcoming if the lecturer provides opportunities for short personal and individual talks, preferably some little time after the lecture when the youth has had time to formulate the most prominent questions to which an answer is desired. In practice, these questions will generally be found to be at once a clue to the real difficulty and an unconscious masking of it devised to preserve *amour propre*! The medical adviser must start with a silent and mental anatomical survey of each case, followed by a physiological review of the individual problem; he or she then proceeds to a psychological examination (using the term very broadly and practically), and only finally formulates advice. The parallel with an up-to-date clinical examination of a patient is obvious, but in the case of the medical adviser to a physical education centre the time taken is very much less since, after some experience, he develops a 'flair' which will enable him to perform all the examinations almost simultaneously, and to arrive very quickly at practical conclusions based on scientific study.

Then follows the insistence on the youth of either sex taking himself or herself as the standard, both as regards the present state and the future progress. Mechanical apparatus such as the weighing machine, stethoscope, tape measure, dynamometer, and that for vital capacity examinations have their uses in some cases, but are of relatively little general value, being based on inexact scientific principles in respect of routine usage. Research will, doubtless, render these and other methods of assessing health and muscular efficiency of much greater value than they are at this moment, but reliance on them as they are at the moment is bound to breed disappointment for the medical adviser and his client alike.

NOTE.—A discussion of the part played by 'rhythm' in exercise will be found in Knudsen's *Textbook of Gymnastics* (1937). He emphasizes the importance of associating rhythmic practices with static muscular work, pointing out that in the former the

muscles do not work to their full extent nor with full power. This has certain advantages in some conditions, but tends to discouragement if used excessively, for the beneficial results are not manifest to the pupil as in exercises in which skill and achievement are objectives. They therefore fail from the point of view of securing standards of health which youth can quickly appreciate.

IV

MUSCLE FUEL

THE old idea that the energy required for muscular contraction is entirely produced by the breaking down of proteids has passed away, but it has left behind it certain views about nutrition and diet for which no scientific basis exists; some are only harmless fads, but others retard the adoption of sane methods of physical education and excite useless controversies. The proof that the primary fuel of muscular action is carbohydrate was first given by O. Meyerhof (1919 and onwards) and A. V. Hill (1923 and later), but in 1911 N. Zuntz had put forward the now generally held belief that all the foodstuffs (proteids, fats, and carbohydrates) were concerned. Even to-day the importance of oxygen is underrated, and hence it will be dealt with in this chapter (in order that it may be indicated that mere feeding is not enough) even before nutrition questions are discussed. Hill believed that fat had to be converted into carbohydrate elsewhere in the body before it could supply muscular energy. The rough statement that proteid builds muscles, carbohydrates supply most of the energy, and fat is an ordinary storage material of energy, may be accepted for the moment, though it will have to be modified somewhat later.

Samson Wright (1936), reviewing the whole question, concludes that carbohydrates furnish more than 50 per cent. of the energy content of most dietaries, and are cheap and easily obtainable. If the supply of these is inadequate, the fats are incompletely oxidized in freeing energy, and some poisonous substances appear in the body, but both carbohydrates and fat can replace each other to a considerable extent in the task of energy production so long as a diet of 3,000 calories does not contain less than about 700 calories (nearly 2½ ounces) of fat. He quotes Starling (1919) as

having proved that the fat ration should always be relatively high when there is a large increase in the energy expenditure of the body, either in the form of work or in consequence of exposure to cold. Proteids contain sulphur and nitrogen which are essential for the replacement of the wastage of the muscular framework of the human 'battery'. Wright gives the composition of an average normal diet as: proteid, 3½ ounces (410 calories); fat, 3½ ounces (930 calories); and carbohydrate, 14 ounces (1,640 calories), the caloric total being 2,980. It must be noted that some persons have an idiosyncrasy in the form of poor digestion and assimilation of fats, and should avoid them.

It has been found that men perform work with greater difficulty and become much more fatigued on fat than on carbohydrate diets. Y. Henderson and H. W. Haggard (1925), as a result of experiments performed on a Yale rowing crew, found that sugar was not the sole fuel though it was the most immediately available to supply the energy for muscular work, and caused less distress to the worker. Their data indicated that at least two-thirds of the energy in athletes was derived from fat, and they thought that it would be very helpful in the prevention of overtraining and in the acquiring of a 'good wind' if the fat consumption was reduced to a figure which would keep the bodily respiratory quotient up to 0·85 or even 0·9. (This respiratory quotient is the figure representing the relation between the oxygen absorbed and the carbon dioxide eliminated. For carbohydrates it is 1; for fat it is 0·71; and for proteids about the same as for fat.) It is possible that fatigue (often synonymous with acidosis) would be lessened by such a reduction of fat.

The liver is the main storehouse in the body of glycogen —the most prominent carbohydrate source of energy— derived mainly from the carbohydrates in the food but also capable of being formed from proteid and fat. Glycogen also occurs in the muscles, but Y. O. Choi (1928) has shown

that in this situation it serves only as the mother substance of lactic acid and so restores local wastage of the latter. Glycogen cannot readily be built up in the muscles in the absence of insulin—a point of clinical interest in diabetes. The discharge of glycogen from the liver in violent exercise is marked, but the call for it is diminished in the better-trained persons. This is one of the benefits gained by reasonable systematic training. Adrenaline causes this discharge, and thus the sugar content of the blood rises before an athletic feat with which excitement is associated. The part played by the liver in fat metabolism has been more fully discussed by C. H. Best (1934).

E. P. Cathcart (1925) does not altogether agree with the modern view that muscular activity does not directly cause the break-down of proteid in the muscle. He believes that at any rate in excessive work some of this is forced into use as a provider of energy. Embden and Hábs (1926) are inclined to support this view, though other authorities have disagreed.

The point is of considerable importance, both scientifically and practically, and further research is needed. O. Peczenik (1927) records experiments showing that proteid-rich dietaries stimulate activity and strengthen endurance. The question must be left open, but it would be interesting to know whether different dietaries should be recommended for such very different activities as long-distance running, swimming, climbing, sprinting, &c.

OXYGEN AND MUSCULAR ACTIVITY

Oxygen is an essential factor in the restoration of energy to a muscle which has been in action. Provided that there is an ample supply, the muscle-fibres take up what they need, but it must be remembered that there are no storage facilities in this respect in the body. While at rest the body requires each minute a supply of 7 to 8 ounces by volume of oxygen, and in vigorous exertion up to ten times as much.

It has been shown that lactic acid accumulates in a muscle which has been deprived of oxygen, and that the subsequent supply of this gas 'recharges the battery' in normal circumstances.

In prolonged exercise a balance has to be struck between the processes of discharging and recharging the battery, as indicated in Chapter II. In short sprints this balance need not be maintained since the recharging can be left until the period of rest, but excessively violent exercise cannot be maintained because the lactic acid content of the muscles rises quickly to the fatigue maximum, which is about 0·28 per cent., stopping further muscular contraction. At the start of walking or running at a moderate pace the rate of recharging starts from zero and increases for two minutes or more until it balances the oxygen consumption (an important factor in the occurrence of 'second wind'). At first lactic acid is produced in the muscles at an increased rate, and the oxygen consumption is accelerated in dealing with it. The speed of the chemical changes increases as the temperature rises. There is thus brought about quicker breathing and pulse-rate. Finally, a 'steady rate' results, as has been illustrated graphically by A. V. Hill and H. Lupton (1923).

Hill and his collaborators have pointed out, further, that an 'oxygen debt' ranging from a few cubic centimetres up to 17 litres may be acquired, according to the degree of training of the individual subject and his innate capabilities. This 'debt' represents the excess in litres of oxygen for the period of exertion over the amount of this gas taken in by the lungs and transported to the blood during the period of exercise. Its chief sign in the body is the amount of lactic acid. Jumping violently for 10 seconds was shown to produce 20·3 grammes of lactic acid and to cause an oxygen debt of 2·5 litres; the corresponding figures for such jumping for 20 seconds were 44·6 grammes and 5·5 litres, and for running 225 yards in 23·4 seconds 71 grammes and 8·7 litres.

A man's ability to take in oxygen from the air and to accumulate an oxygen debt determines how much strenuous work he can do without exhaustion. (It is most pathetic to see young runners in training for sports plodding along with their chests contracted by bad carriage so that their intake of oxygen is obviously restricted. Will no one teach their trainers some practical science of breathing?) Laboratory tests can define this ability on precise lines, and so supply one means of testing the comparative values of different schemes of training.

Meanwhile attention is merited by the most useful booklet *Athletics for Health* by J. E. Lovelock (1937), in which principles of training are stressed. He indicates how general health may be raised through sport; outlines the principles of special athletic training for all track and field events; summarizes the training for middle-distance racing; discusses the acquisition of 'style' and its implications; and comments on the tactics of competitive work. Style is defined as 'ease and economy of effort', correct physiological conception which is interpreted practically. The value of the relaxation of non-acting muscles is emphasized, as also in the part played by limb co-ordination and rhythmical movement. The importance of all this as regards oxygen and muscular activity is obvious, and standards could be defined to determine the efficiency of the youngsters relatively to their real capabilities.

Tests are also useful in showing what progress has been made during a course of training. 'Endurance for Scouts' is the heading of Chapter VI in Lord Baden-Powell's *Scouting for Boys*; it is time that some systematic testing for the development of 'stamina' was made available for the use of Scoutmasters and other national instructors of youths, for without it the new campaign for physical education will be without standards in one respect! Grading on a scientific basis will also be possible of younger and older enthusiasts who undertake physical

training, so that mistakes are not made and no harm comes to the trainees.

A well-trained athlete may be able to absorb 4,000 cubic centimetres (140 ounces by volume) of oxygen per minute, and acquire an oxygen debt of nearly four times that amount. When the maximum debt has been incurred, bodily activity is arrested. Hill points out that the time at which exhaustion will ensue in any case can be predicted by calculations based on these considerations, and consequently a safety limit can be defined. His original articles must be consulted for further details, but it will be a calamity if the practical value of this work is not widely recognized.

H. Briggs (1920) has investigated certain related aspects of physical exertion, fitness, and breathing. He distinguishes between a 'normal-load', a 'crest-load', and an 'over-load'. In the first the intake of oxygen balances the need of the body while the work is being done. In the second the supply is still equal to the demand, but all the oxygen-supplying mechanisms are working to full capacity, and can do no more in any circumstances. In the third the intake of oxygen is inadequate, the oxygen account is 'overdrawn', and the oxygen debt is steadily rising. The 'crest-load' diminishes in disease and is increased by training. It decreases also if physical exercise is neglected, but is raised by even moderate daily exercise. Schneider points out that a fruitful line of research would be to determine how close to his 'crest-load' a man may work day after day and still remain fit. Each worker requires in any case some margin below his 'crest-load' to allow for any spurts which may have to be made. The endurance of any person is limited by the capacity of his heart to undertake the necessary work, but his final effort is stopped actually by the oxygen debt.

Of the various factors which are concerned in the supply of an adequate amount of oxygen to the lungs, four may be noted: the volume of air per minute taken in by the lungs;

the oxygen capacity of the blood; the rate of unloading of oxygen into the tissues; and the amount of blood pumped out by the heart each minute. Deep breathing increases only slightly the degree of alveolar pressure, but this pressure determines the passage of oxygen into the blood; it is therefore of only temporary value, and the abuse of deep breathing exercises leads to undesirable consequences to which reference will be made later.

The oxygen-carrying capacity of the blood varies in different individuals, and is measurable in terms of the haemoglobin percentage. The unloading of oxygen into the tissues is similarly variable; it is increased by muscular activity, especially in those who are accustomed to exercise. As a rule the output of the heart during exercise parallels the consumption of oxygen. Increased pulmonary ventilation unaccompanied by increased blood-flow would do little to improve the blood-supply to the muscles.

Considerations such as the foregoing illustrate the futility of emphasizing the paramount importance of only one factor, such as nutrition, and the dangerous folly of those who neglect the scientific side of physical education. They indicate also how the medical adviser to a sports club or a gymnastic institution can do an immense amount of useful research work even though he has no laboratory facilities. But, more than all, they show the immediate importance of collating what is already known with the new discoveries which are being made every month throughout the world; this would be possible in some centre such as a national physical education college.

V

NERVE FACTORS IN MUSCULAR ACTION

CONSIDERABLE advances have been made of late in the understanding of the neurological aspects of muscular contraction, and a brief review of the main points is necessary before proceeding to more general topics in physical education. Those who require fuller details will find a more complete discussion in Professor Samson Wright's *Applied Physiology* (1936).

Posture is the basis of movement, but neurological reflexes as well as psychological factors are intimately concerned in the body at rest (posture) and the body in movement (carriage), and the ignoring of these has been responsible in the past for much faulty teaching leading to wild and unscientific speculations. In some exercises the muscular work is very slight, and the nerve activities are of prime importance, whether they are instigated by the conscious will power, or are of reflex origin, or have a psychological significance. In this chapter the first two of these will be mainly considered.

THE BRAIN AND CONSCIOUS MOVEMENT

It is now generally agreed that co-ordinated and purposeful muscular actions result from stimuli originating in the Betz cell or pre-Rolandic area or true motor cortex (alternative names of differing significance for the same part of the brain) and the pyramidal tracts, together with the frontal eyefield with its descending nerve-fibres, connecting with the lower motor nuclei in the brain stem and spinal cord.

Samson Wright remarks: 'It must be remembered that we are not aware of the actual muscles involved in any movement; we simply notice the end result, which is displacement of joints or segments of the body in a certain direction and to a certain extent. Many of the component

parts of a "voluntary" movement are entirely outside consciousness, and have little of a voluntary character about them.' No sharp distinction can be drawn between 'voluntary' and 'automatic' movements from a physiological standpoint, although the first tend to pass into the second in the course of physical education, psychological considerations also being involved.

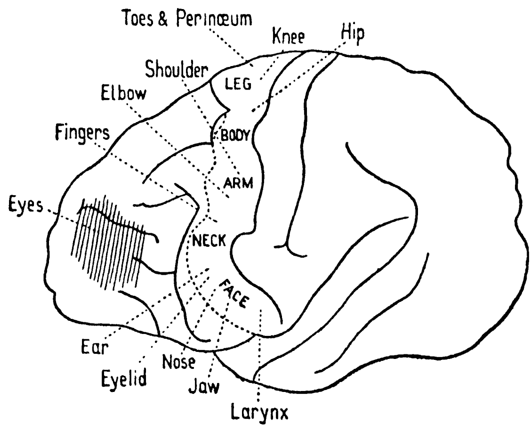

FIG. 1. Diagram of outer surface of cerebral cortex of the chimpanzee to show the arrangement of the motor centres.—After Sherrington. (From Samson Wright's *Applied Physiology*.)

Many groups of muscles play a part in effecting a quite simple voluntary movement; a simple summary of such group action was contributed by Professor Blair to the May, 1936, issue of the *Journal of the Chartered Society of Massage and Medical Gymnastics*. Thus there are (*a*) prime movers or agonists, sometimes termed protagonists; (*b*) antagonists; (*c*) synergists; (*d*) co-operating muscles (Kinnier Wilson, see *Modern Problems in Neurology*, 1928); and (*e*) fixation muscles. There is obviously a very complex co-ordination of nervous impulses implied, the consideration of which lies outside the scope of this book—apart from the reiterated insistence on the importance of more scientific study of muscular movement in exercise, from the neurological as

well as from the psychological standpoints. Some of the practical points arising will be dealt with later in this book, more particularly in Chapters XVII and XVIII.

The corpus striatum part of the brain does not directly control voluntary movement in man, but it is concerned with the regulation of posture (Kinnier Wilson, 1914 and 1925). It has apparently few connexions with the motor cortex, receiving its afferent impulses from the thalamus, an important relay station between the centres devoted to the receipt of nervous sensations and those concerned with certain motor impulses. A practical deduction may at once be drawn, namely, that the attainment and maintenance of a good posture depends on other things than voluntary or disciplinary exercises, which partly accounts for the imperfect physique in some respects and evil muscle habits of many who have passed through courses of physical training! The extravagant claims of many who advocate various forms of physical education as regards the obtaining of a healthy nation may at once be discounted, unless such scientific factors are considered much more carefully than has yet been the case. On the other hand, closer attention to these will evoke better results more quickly and more permanently.

CONDUCTION OF NERVOUS IMPULSES

Three main groups of nerve fibres descend from the motor areas of the brain: (*a*) the pyramidal or cerebrospinal tracts which arise from the Betz cells of the Rolandic area, and are concerned with discrete voluntary movements; (*b*) cortico-nuclear fibres from the second frontal convolution, which control voluntary movements of the eyeballs; and (*c*) the fronto-pontine fibres which play a part in the performance of crude group movements of various parts of the body. Adrian has shown that voluntary movement is graded by the frequency of the motor-neurone discharge and the number of motor neurones in action—the force of

the muscular contraction and the number of muscle-fibres in action being thus appropriately regulated according to the demand of the occasion.

Stimulation of the motor nerve-supply of a muscle produces a diphasic electrical reaction, the current being deflected first in one direction and then in the opposite one; this electrical response is completed long before the end of the contraction phase. A posturing muscle receives impulses at a low rate (5 to 20 a second), and the chemical changes going on in it are low; there is therefore a slow discharge only from the anterior horn cells of the spinal cord; it is probably asynchronous, bringing about an even muscular tension, different fibres being involved in turn. A muscle in active contraction so as to bring about movement is being much more actively stimulated, and a greater proportion of the fibres is being excited, so that fatigue ensues more rapidly than in the purely tonic muscle.

The motor innervation of both red and white muscle-fibres is similar; both occur in varying proportions in various muscles according to their functional necessities. The red fibres seem to be more concerned with maintaining postures, and the white for executing active movements. No muscle is solely devoted to the maintenance either of posture or of active movement, these functions being capable of being exercised by all muscles, though with varying degrees of efficiency.

NERVOUS MECHANISM OF POSTURE

Magnus (1924 and 1925) has emphasized the importance of the vestibular apparatus of the ear in maintaining posture; it influences in this respect the eyes, trunk, and limbs; the cerebellum; and the cerebrum. Its importance in balancing exercises is therefore obvious, and the relation of the attaining of the correct body balance in the correct way is a sadly neglected part at present of physical education. The red muscle-fibres are probably more concerned than

the white in balance adjustments. The following two diagrams illustrate the nervous mechanisms involved:

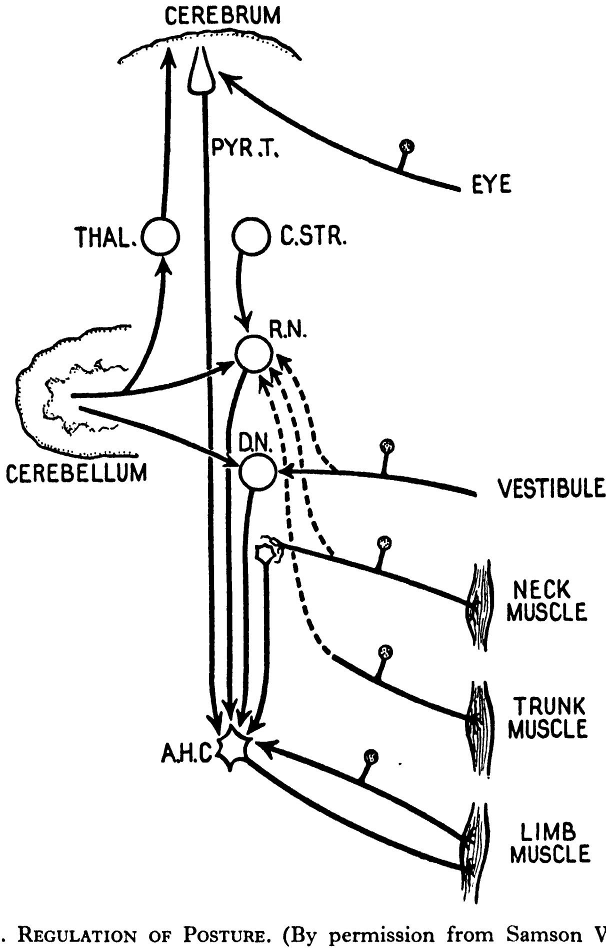

FIG. 2. REGULATION OF POSTURE. (By permission from Samson Wright's *Applied Physiology*.)

THAL. = Thalamus; PYR.T = Pyramidal tract; C.STR. = Corpus Striatum; R.N. = Red nucleus; D.N. = Deiters' nucleus; A.H.C. = Anterior horn cell.

Injuries of the pyramidal tracts lead to the appearance of the posture of human decerebrate rigidity (see article by Samson Wright in the Congress Number for 1936 of the

Journal of the Chartered Society of Massage and Medical Gymnastics). Disease of the corpus striatum causes a characteristic rigidity, the body assuming an attitude of generalized flexion (Kinnier Wilson, 1914), there being also

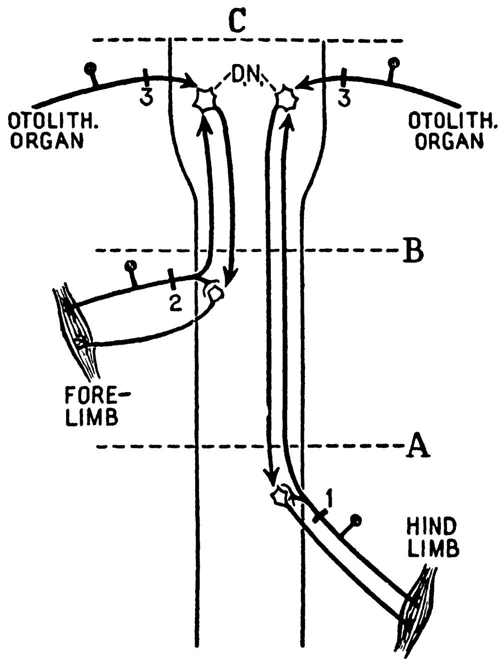

FIG. 3. POSTURE IN SPINAL AND DECEREBRATE PREPARATION. (By permission from Samson Wright's *Applied Physiology*.)

A and B represent trans-sections through the mid-thorax and mid-cervical regions of the cord respectively, while C represents a section above Deiters' nucleus (D.N.). In the case of the hind limb, section of the posterior nerve roots (at 1) abolishes tone; in the fore limb of the decerebrate animal the vestibular nerve must be cut also (at 3).

tremors and disturbances of movement. Injuries of the cerebellum give rise to a general decrease of tone of the body, especially in the limbs.

The cerebellum is an important factor in the regulation of posture, probably guiding the cerebral cortex in the initiation of voluntary movements. Stimulation of it tends to produce flexor attitudes, and such stimulation may be of

psychological origin—another important consideration in devising schemes of physical education, to which attention will be drawn later. It is also related to clumsiness of movement owing to lack of muscular co-ordination, to carriage, and to gait, but further details would be out of place here, particularly since much more research is required before detailed conclusions can be enunciated.

REFLEXES

Pavlov distinguished between unconditioned reflexes (such as the knee-jerk, defence reflexes such as the flexor muscle response, &c.) and the acquired or conditioned reflexes which differ from the former in being particular to the individual and not common to all persons. The latter are built up on the basis of inborn reflexes, and are of special importance to us in providing a mechanism for ensuring the continuance of good muscular habits when the hour or more of active tuition has ended.

This form of 'conditioned reflex' has been sadly overlooked by most schools of physical training, a tendency by the pupils to assume faulty postures being often clearly observable after a lesson which has involved muscular or nervous strain. Such a tendency implies that real physical harm is being done by the training. The way in which such conditioned reflexes may be used practically in physical education is described in detail by McConnel and Griffin (1937).

The establishment of positive or excitatory conditioned nervous reflexes, as indicated by Samson Wright, may be further detailed in view of their applied importance to physical education, the essential conditions being as follows: (1) The animal must be in good health, the nervous system must be alert, and there must be complete freedom from all simultaneously operating influences. (2) The external stimulus which is to become the conditioned stimulus must begin to operate before the unconditioned stimulus is

applied; thus in Pavlov's original experiment the bell began to sound before any food was put into the mouth in order to stimulate salivary secretion. The bell continued to ring while the animal was being fed. (3) Stimuli at first without excitatory influence can later by suitable procedures have the power of excitation conferred upon them and become conditioned stimuli. (4) It must be recognized that inhibitory effects may be exerted by the non-continuance of stimuli for a sufficient length of time or by opposing stimuli, whether of psychological or other origin.

Further references to this subject were recently made by Samson Wright in the Special Congress Number of the *Journal of the Chartered Society of Massage and Medical Gymnastics* (1936), as well as by J. Lehmann in the *Journal of Physical Education and School Hygiene* (November 1936). It must also be remembered that such conditioned reflexes may be originated by chemical changes in the body, the effects of disease, &c. For further details of their neurological aspects reference should be made to Samson Wright's *Applied Physiology*.

MUSCLE TONE

The state of mild reflex contraction which is termed muscle tone is not due to the sympathetic nervous system, but is caused by afferent sensory impulses to the brain from the sense organs in the skeletal muscles and to a less degree from the vestibular apparatus and the eyes. It is probably due to a slow asynchronous discharge from the anterior horn cells of the spinal cord, which produces a partial tetanic condition and can be long maintained. Both the red and pale fibres are concerned in its production. It follows that muscles are receiving a continuous supply of nerve impulses, even while at rest.

VI

GENERAL PRINCIPLES IN RESPIRATION

WITH the honourable exceptions of a few physical training systems, few devote attention to the most important subject of respiration, and even in these the methods used are rarely based on scientific principles. The unfortunate dictum that muscular activities evoke the necessary respiratory activities is a very imperfect generalization. Without entering very much into the attendant controversies it is not difficult to emphasize some of the outstanding facts in this connexion, and to indicate the conclusions which have practical application. By way of preface, attention may be drawn to four reasons 'why we breathe'.

1. The various bodily activities require an adequate supply of oxygen from the air. As has been shown, this gas is essential for the building up of the energy-producing substance in the muscles. Speed, strength, and endurance cannot be gained or maintained without it; they can often be increased by increasing its intake, adding power and joy to living. Fatigue and faintness can be quickly remedied by suitable breathing exercises. Just as bad muscular habits cripple a life (McConnel and Griffin, 1937), so do bad breathing habits also; good habits of breathing can be acquired on the same lines of training as have been found good in acquiring other habits.

2. Breathing serves to remove the unwanted proportion of carbon dioxide produced by muscular action and other bodily activities, and also some other waste products such as water. In this connexion the importance of the skin as a respiratory organ should not be overlooked, nor the 'tissue respiration' which is always going on as part of metabolism (the chemical and other changes in the body). It has been shown experimentally that varnishing of the skin leads to

death from suffocation, even if the lungs are fully active. An early experiment, the covering with gold-leaf of the skin of a boy in an ancient Roman Triumphal Procession, proved this, such suffocation being due to the retention of waste products in the body. Arguments for nudism based on this contain scientific fallacies, however, so must not be pressed too far!

3. As will be explained later, an adequate supply of oxygen is required for the maintenance of a correct degree of alkalinity of the blood and of the body tissues. Dietary considerations also come into this question to some extent, as well as the varying degrees of muscular activities.

4. Breathing in the correct ways permits the healthy stimulation by oxygen of the general circulation, particularly by strengthening the heart.

With such considerations in mind it is difficult to understand the neglect of breathing in the past by leaders in physical education. It must be remembered in palliation of this neglect that only in recent times has there been any exact scientific study of the subject, and that medical advisers have now a great deal of work to do to broadcast what is known. Galloway (1937) states that the objectives of breathing exercises are: to increase vital capacity, mobility of the chest walls, the range and strength of the respiratory muscles, and the improvement of their co-ordination. With some qualifications to be noted later, these objectives can be accepted. He adds that deep breathing exercises ease the strain on the heart in the earlier stages of physical training, but some authorities will hardly agree with him whole-heartedly that bad habits and lack of co-ordination in breathing can be corrected more easily by specially designed exercises. It is not invariably true, also, that deep breathing exercises will effect a marked improvement in the breathing during ordinary exercise.

The respiratory act depends on many factors, such as the condition of the respiratory centre in the pontine and upper

medullary parts of the brain (T. Lumsden, 1923); the respiratory surface in the lungs available for use; the replacement of the respiratory air; the circulation of blood through the lungs and its oxygen tension; and the maintenance of the metabolic changes in the body tissues, &c. The respiratory system may be considered to comprise a conducting mechanism; a respiratory mechanism; and an air-changing mechanism (E. C. Schneider, 1936). Medical practitioners are too prone to concentrate more particularly on the first of these, and must not forget the other two in practical work with athletes and others undergoing physical training.

The replacement of the respiratory air takes place in the lung alveoli, where it has been estimated that the blood is brought into contiguity with the air over a surface of some 100 square metres (over 110 square yards)—a useful figure to bear in mind when lecturing on the subject, since mention of it tends to make the audience sit up, cramp their chests less and breathe with less postural restriction, and consequently pay more attention! The muscles concerned in this replacement include the diaphragm as well as the intercostals; too much relative importance is often given in practice to the accessory muscles of respiration (those connecting the arms with the trunk in particular) which are relatively unimportant, except in such conditions as those calling for artificial respiration. Well-known physiological text-books which deal with this subject include those by Haldane and J. G. Priestley (1935), C. G. Douglas and Priestley (practical determinations; second edition, 1937); Schafer, and E. H. Starling.

RATE AND DEPTH OF BREATHING

The average man requires nearly 9 ounces by volume of oxygen per minute while at rest, and breathes fifteen to eighteen times in that period, but wide variations are not uncommon. The term TIDAL AIR is given to the amount

breathed in or out of the lungs with each quiet respiration, the average figure being 12 to 18 ounces (350 to 500 c.c.). SUPPLEMENTAL AIR is the additional amount which can be expelled by a maximum effort after a normal expiration; the average figure being 53 ounces (1,500 c.c.). The term COMPLEMENTAL AIR indicates the amount which can be taken in by a maximal inspiratory effort after a quiet inspiration; the average figure is the same as for supplemental air. The VITAL CAPACITY is the sum of the preceding figures, an average figure being 123 ounces (3,500 c.c.). The RESIDUAL AIR is the amount which remains in the lungs after a maximal expiration, the figure being 35 to 53 ounces (1,000 to 1,500 c.c.). ALVEOLAR AIR consists of the sum of the supplemental and the residual air, and amounts to about 106 ounces (3,000 c.c.). The DEAD SPACE AIR is found in the air passages, nasopharynx, trachea, and bronchi; it does not reach the alveoli of the lungs, and consequently is not concerned in the gaseous exchanges. It usually amounts to about five ounces (150 c.c.), or 25 to 30 per cent. of the tidal air, except when there is voluntary or emotional deep breathing when the percentage rises without increasing perceptibly the gaseous exchange—a fact which enthusiasts for deep breathing exercises frequently overlook! Such an increase also occurs (Samson Wright) when untrained subjects are tested by unfamiliar breathing apparatus, and this must considerably reduce the value of dead-space determinations.

These figures are affected by physical training; the trained man breathes more slowly and more efficiently. They are also affected by the extent to which both the diaphragm and the intercostal muscles are used. The exact value in practice of spirometer estimations of the vital capacity is a disputable point, but it seems to give a very rough idea of the functional ability in some cases—hence its present popularity. It is known, however, that vital capacity is increased by exercise in children and adolescents;

on the other hand some climbers and Marathon runners have poor vital capacity figures.

The whole question is obviously a complicated one, demanding further elucidation by scientific research, but in the waiting time we must get on with the work of physical training, using such 'rule of thumb' methods as the spirometer without attaching too much importance to its readings taken by themselves. To this it may be added that it costs the body about 5·5 cubic centimetres of oxygen to move 1,000 cubic centimetres of air into and out of the lungs. Slow and deep breathing is therefore probably the most efficient and economical type of respiration; within limits it promotes the most adequate pulmonary ventilation.

The total volume of air breathed per minute (MINUTE VOLUME) ranges from 106 to 350 ounces (3,000 to 10,000 c.c.), the average being about 280 ounces. It must be realized that the newly inspired air does not enter the alveoli at once; the alteration in the quality of their air content is brought about by a continuous process of diffusion between the alveolar air and that in the smaller bronchi, which in its turn is modified by the air in the larger bronchi and the dead space. In this way the delicate lining membrane of the alveoli is protected from sudden changes in the temperature, chemical composition, and pressure of the atmosphere. The term alveolar air represents a physiological or functional and not an anatomical conception. The efficiency with which the tidal air washes out the alveolar air depends largely on the depth of the breathing; if this depth were reduced to the content of the dead space, alveolar ventilation would cease.

A summary of the main factors concerned in the regulation of the respiration is shown in Fig. 4.

An increase of carbon dioxide in the respired air quickens the rate of breathing—a fact utilized in the treatment of shock, for instance in the course of a surgical operation, by the administration of carbon dioxide and oxygen. The first

gas acts mainly directly on the respiratory centre in the brain, and reflexly also by stimulating the sensory nerve-endings in the carotid sinus region and the aortic arch, thus sending excitatory impulses to the centre. This explains partly why the rate of breathing increases, there being an

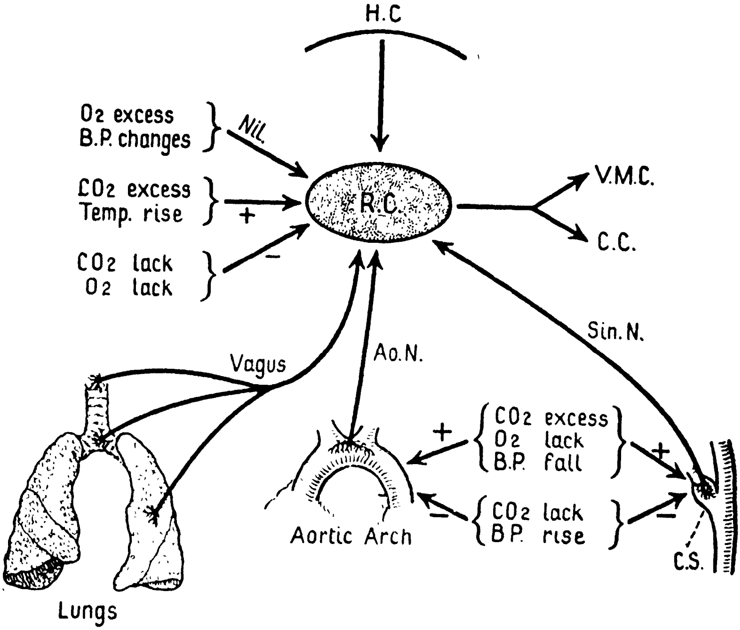

FIG. 4. REGULATION OF RESPIRATION. (By permission from Samson Wright's *Applied Physiology*.)

R.C. = Respiratory centre; H.C. = Higher centres; C.C. = Cardiac centre; V.M.C. = Vasomotor centre; C.S. = Carotid sinus region (including carotid body); Sin.N. = Sinus nerve; Ao.N. = Aortic nerve; + = Stimulates breathing; − = Depresses breathing.

increase of carbon dioxide in the blood; another factor being the demand of the muscular tissues for a greater oxygen supply for recharging with energy.

If the inspired air contains an increase of carbon dioxide it cannot eliminate efficiently the carbon dioxide in the alveolar air; hence is deduced one of the reasons for emphasizing the greater value of physical exercises in the

open air rather than indoors. Haldane and Priestley have shown that such excess of carbon dioxide first increases the depth and later the frequency of breathing, the first contributing considerably more than the latter to the increased ventilation of the lungs. Muscular exertion in such carbon dioxide laden atmospheres is impaired, and the fatigue products accumulate more rapidly. Leonard Hill has shown how more important it is to have moving air rather than still air, even though there is a higher percentage of carbon dioxide in the first; the air currents stimulate the skin. Compare the respiratory stimulus of cold water applied to the skin.

The respiratory centre in the brain possesses an inherent rhythmicity, analogous to that of the sino-auricular node of the heart. It has been shown that in quiet breathing the diaphragm and the external intercostal muscles are being stimulated through their motor nerves subtetanically at low rates of about 25 per second; the muscle pull is steady and not tremulous because the central nervous discharge is asynchronous, and the various motor units are out of phase. As in skeletal muscle activities, only a proportion of the muscle fibres are in action. In deep breathing the discharge rate is more rapid (40 to 100 per second), more synchronous, and of longer duration, while the proportion of active muscle-fibres rises. The inspiratory muscles (diaphragm and external intercostals) contract more forcibly; more fibres are pulling more strongly and for a longer time, and a deeper inspiration results.

It is generally held that in quiet breathing inspiration is the active phase of respiration, and expiration the passive, but in certain abnormal states there may be active expiratory efforts. Moreover in deep breathing expiration seems to be an active process, and to be capable of being intensified by training. The importance of 'fully emptying the lungs' is often urged, but this phrase must be understood to have no precise meaning. The metabolic rate (chemical

changes in the body tissues) normally determines the pulmonary rate, and this latter is consequently variable. Efforts to regulate the breathing according to some timing of muscular actions will therefore fail unless determined by the physiological necessities of the occasion, and various persons will differ in their degree of capability of adjustment.

Here, again, is brought out the difficulty of devising programmes of physical training without reference to physiological considerations, often rather abstruse to the layman, but damage to health may result in some cases if an attempt is made to exert disciplinary measures to secure a desired 'rhythm' in defiance of these considerations. An instructed medical practitioner will be able to help to adjust differences between the pupil and the system on such occasions, with benefit to both. He will also be able to deal with complications due to individual faults in the conducting mechanism of respiration.

VII

PHYSICAL EXERCISE AND RESPIRATION

VARIOUS observers have reported that the ventilation of the lungs during physical exertion is nearly always sufficient to permit full saturation of the blood with oxygen. J. Lindhard (1934) scoffs at deep breathing exercises at any time, but cites the investigations of Liljestrand (1917), even though the latter seem to show the possibility that continued training may facilitate the work of respiration when a greatly increased ventilation is desired. He makes an exception, however, in the case of the breathing exercises advocated by Guts Muths, in which large groups of muscles are brought into activity by movements which do not make serious calls on the central nervous system because they occur reflexly. Lindhard admits that breathing exercises in general seem to do no harm, even though quite irrational in his opinion; he thinks, however, that later in life there may be symptoms of 'positive derangement of the vital functions of the organism', a condition not further described. To some readers of his famous treatise this part of Lindhard's argument will seem curiously weak logically, but in the present discussion we are concerned with the scientific basis of respiration and not with the expression of such groundless and sweeping generalizations.

Other things being equal, pulmonary ventilation will be proportional to the metabolic rate (Schneider, 1936). His figures indicate that such respiratory changes as minute volume, frequency, and depth of breathing correlate with the amount of work accomplished per minute so long as the load of work is moderate, but above the crest-load the ventilation of the lungs becomes excessive, and yet cannot meet the requirements. Data bearing on this have been obtained by Y. Henderson and H. W. Haggard (1925), and by S. G.

Mudd and J. H. Means (1925) in the case of normal, obese, cardiac, and anaemic persons. In the first case it is shown that the minute volume (measured in litres of air) rose from 6 in bed and fasting to 8 when standing, to 26 when walking at the rate of 4 miles an hour, to 43 during a slow run, and to 65–110 during maximum exertion; the corresponding figures for litres per minute of oxygen consumed were 0·24, 0·36, 1·2, 2·0, and 3 to 4. The second pair of authors found that in response to physical effort there was a more marked increase (one-third more) in the total ventilation of the lungs after standard exercise in obese persons rather than in normal ones, this increase being dependent not only on the increased weight but also on a diminished cardiac reserve.

As mentioned previously, the trained man uses much less air than the untrained for a like accomplishment of physical work. This was estimated by E. C. Schneider and G. C. Ring (1929), who found that the improvement was slightly in evidence by the second week of training, the maximum reduction being reached in four to six weeks. Within four to six weeks after the stopping of training the minute volume had nearly reached the level before training began. There seem to be grounds for the belief that with repetition of such periods of training spread over a few years, especially in youth, the maximum reduction is reached more quickly in the later periods, and that this then holds good during middle age. The body learns how to adapt itself more quickly and effectively to such demands upon it, and such knowledge is not lost.

Here is evidence supporting the campaign for physical training begun in youth, even though such training may have to cease owing to the obligations of later life. Not only does the power of endurance remain or be relatively easily regainable, but there may be expected to be other benefits in the form of enhanced resistance of the body, especially of the heart and circulation, to the onslaughts of certain

diseases. More research is strongly indicated in order that such benefits may be defined more precisely.

M. S. Pembrey and others have tilted at the insistence on nasal breathing which has assumed the importance of fetish worship. With N. W. MacKeith (1924) and others he has reported observations on the adjustment of the human body to muscular work. He admits the value during rest of the inspired air passing over the moist surface of the nose and pharynx, but points out that in vigorous exercise definite advantages attend mouth breathing, there being less resistance to the entry and exit of air while the moist vascular surface of the mouth assists in the cooling of the body. The dog is a notable instance of the adoption of this modification of breathing, but it might be added that in training some definite gain accrues from the deliberate disciplining of the respiratory function, which is perhaps not quite such a mechanical automatic procedure as Lindhard seems to think. It is, however, indubitable that the disadvantages of mouth breathing have been grossly and unscientifically exaggerated.

When physical exertion rises to the degree of an overload, frequency of the respiratory rate augments excessively—another phenomenon which becomes less annoying in the process of physical training. During exertion the depth of breathing increases, and reference must again be made to the part played by the 'dead space' (including the nasopharynx, windpipe, and bronchi) which was rather summarily dismissed in the last chapter. Although this is a disputed point, it seems probable that its capacity varies during exercise. Assuming that it has the power of enlarging during exercise, it is obvious that the air in the innermost parts of the lungs will be more frequently changed, and that the blood will have greater access to oxygen supplies. Moreover, it does not seem unlikely that such enlargement could be brought about by suitably designed breathing exercises, and be consequently effected more speedily and

completely when it is desired during active sports and exercises. Here there is scope for more clinical and laboratory research.

DIAPHRAGMATIC ACTION

It may be added that Y. Henderson and J. S. Haldane believe that the size of the 'dead space' is definitely increased by deep breathing, especially when the diaphragm is used. The importance of using the diaphragm is thus emphasized, and it is hardly yet realized what a great handicap is imposed on civilized humanity by their bad postures when sitting (McConnel and Griffin, 1937). Faulty postural habits are easily acquired but not so easily shaken off unless the problem of releasing oneself from them is faced in the correct way.

Keith (1909) and others held that the function of the intercostal muscles was merely passive, the diaphragm doing the main work in respiration. Wall (1928) argues convincingly in favour of Briscoe's view (1927 and 1931) that both are concerned, quiet inspiration and expiration being effected by the internal and external intercostals. Briscoe stated also that inflation of the upper lobes of the lungs depended on expansion of the upper part of the thorax, combined with tone in the diaphragm, whereas inflation of the lower lobes was dependent on a low level of the diaphragm, and probably on inspiratory descent of the costal portion. He urged the necessity of educating or re-educating the diaphragm after recumbency due to illness. In the supine position the crura of the diaphragm alone contract, the costal part being passive. (This should be noted by teachers of diaphragm exercises.)

It would seem that more attention should be paid to the diaphragm in physical training, and directions for its re-education were given by Briscoe (1927). He pointed out that instructions to breathe deeply resulted usually in thoracic elevation alone, with no epigastric protrusion indicating

diaphragmatic action. Manual pressure downwards on the lower ribs assists its action, as also does assumption of the posture on the hands and knees in children. Further practical hints are given by McConnel and Griffin (1937). Since different postures demand different proportions of costal and abdominal respiration, it would appear to be obvious that physical training should include scientific consideration of specific exercises, devised so as to encourage healthy habits of breathing in various circumstances. A start should be made with the report of Briscoe (1927).

THE EFFECTS OF EXERCISE

When moderate exercise is begun the minute volume and the rate of breathing increase at once; a steady rate is reached in the former in about three to five minutes, and in the latter in two to four. If the exercise is more severe the increases continue for longer before the steady rates are reached. After exercise in moderation the minute volume decreases rapidly during the first minute or two, while the frequency of breaths takes longer to regain the normal (Schneider and Clarke, 1926). The ability to breathe a little more deeply after a race than is normal for the untrained person may, therefore, be considered to have some recuperative value, and in some cases the hint to 'breathe a little more deeply' will be found to be worth while, but no additional distress must be permitted to occur. Here again the value of attaining a better habit becomes manifest, and it can be inculcated as a part of training.

Vital capacity estimations give some indication as to the functional abilities of the respiratory mechanism but, as has been previously indicated, their value can be overestimated. Attempts have been made to establish standards. Thus W. P. Shepard (1924) concludes that influenza and pneumonia lower slightly the vital capacity as a rule, and Peabody and Sturgis (1917) state that in patients with great

physical weakness but with no physical disease of the heart and lungs the lowering is not more than 26 per cent. In a normal person the lowering is rarely more than 10 per cent. of the standard figure, and the medical adviser using this test may thus detect in some people indications of an otherwise unsuspected diseased condition. A. H. Turner (1930), who assesses the average vital capacity of young college women as 3,396 cubic centimetres, relates it to height, weight, and surface area of the body—a point not always borne in mind by those who use this estimation for practical purposes. C. M. Jackson (1927) finds that in the case of young male students the range is 1,400 to 6,500 cubic centimetres, with an average of 4,383. He reiterates a warning against taking the measure of chest expansion as an index of vital capacity.

F. J. Born (1910) found that physical exercise in male college students increased the vital capacity by 625 cubic centimetres, as compared with a gain of 295 cubic centimetres by those who did not indulge definitely in systematic physical recreation. A. H. Turner (1930) supplied comparable figures for women students, while Schwartz, Britten, and Thompson (1928) report similarly on the benefits obtained by young male adolescents. All these determinations relate to investigations in the United States, and figures are wanted for Great Britain with especial reference to physical types and prowess. That prolonged vigorous training does not increase the breathing surface of the lungs has been suspected by Gordon, Levine, and Wilmaers (1924). E. C. Schneider in his text-book on *The Psychology of Muscular Activity* (1936) supplies a most informative critical discussion of the subject based on his own original work and that of others.

It is a great pity that many of those concerned in the task of physical education will not consider the discoveries already made and the opinions deducible before advancing theories which have no scientific basis, and which too often

result in practice in disappointments which retard the progress of the campaign which they are championing. There is already plenty of evidence for the view that athletic training definitely enhances the efficiency of the respiratory function, and that this enhancement is not only a question of the vital capacity. Schneider points out that the untrained man does not seem able to use the maximum ventilative capacity of the lungs.

Training must take into consideration other factors to which reference will later be made. Just as in the past there was too much insistence on the bulk of muscles as an individual factor, so now there is danger of exaggeration of the importance of such details as ventilation of the lungs, the action of the heart, and the composition of the diet, &c. All these factors must be considered in designing any sound scheme of physical training in the correct proportion, but the implied assessment is dependent on scientific research and cannot be left to the vagaries of views held by uninstructed teachers. The task of establishing a sound scientific basis is huge, but by no means impossible.

SOME PRACTICAL POINTS

Breathlessness prevents muscular activity from being continued to a point where irretrievable damage to the heart and lungs might be inflicted. Its incidence protects the young, whereas in the middle-aged muscular failure is often the more obvious safeguard. Collapse occurs more rapidly in youth and is more transient; older workers show more endurance, but recovery from collapse is much slower and less complete. It is important to realize that youth must be trained and not strained, and that endurance tests as part of training must be adjusted to the age as well as to the individual physical capacity of the subject. Adults may undergo more exacting conditions of training, but they must realize at the time, as well as later, that such conditions must not be imposed upon children and adolescents.

This danger is far more widespread than is generally realized by the advocates of physical education.

Between the ages of 14 and 18 the lungs grow very rapidly, and so does the heart, while the arteries and veins remain relatively small. During this stage of life the respiratory efficiency can be increased by suitable regulated games, races, hikes, and gymnastic exercises. Speed exercises can be most effectively employed at about the age of 16 to 17, the small blood-vessels protecting the heart by inducing breathlessness when the danger limits are approached. Undetected rheumatism and pulmonary tuberculosis are real dangers of this period, and the first signs may be a failure to enjoy athletic exercise, though psychological considerations may also be concerned in such reluctance. The stethoscope is not the only diagnostic weapon to use in the latter; vital capacity tests are also useful. Lack of adequate rest for the adolescent is in my opinion a much more serious national menace, as regards tuberculosis, than inadequate nutrition, and medical advisers of athletic institutions will have scores of individual problems to settle in this respect.

Occasional outdoor games are inadequate to promote respiratory efficiency, and hence comes in the importance of indoor gymnasia in which physical training can proceed irrespective of weather conditions. A 'good wind' is a more valuable objective than big and strong muscles, especially at the age under consideration. It has been shown that such indoor exercise continued regularly for four months will increase the average vital capacity of the adolescent by over 4 per cent., but no one should overlook the necessity of taking every opportunity of facilities for sports and games.

The utilization of the respiratory resources, innate or acquired by training, can be improved to some extent at any stage in life, and in the most undeveloped, undernourished, and debilitated, but the extent depends largely

on what was done in the way of physical education in the first twenty-five years of life. Chest expansion may improve little or not at all, and yet great progress be made in health and respiratory ability, so the use of the tape measure in the chest measurement of boys and lads requires discrimination by the medical adviser, and care be taken to avoid unjustifiable discouragement in the case of those who fall behind their fellows. Emphasis may again be laid on the importance of the work of the diaphragm, and on the very great necessity of noting how different persons breathe. Some when told to take a deep breath merely lift the chest as a whole, there being quite obviously no expansion; medical investigation may be necessary for them, for the cause may be structural, physiological, or functional. The changes in the abdominal wall during such deep breathing are also significant (McConnel and Griffin), and merely as a diagnostic procedure this exercise has a value of its own, quite apart from its physiological benefit.

These authors define types of breathing: chest breathing, heaving the chest, normal diaphragmatic breathing, special diaphragmatic breathing, and reversed breathing. Unfortunately, those who prescribe breathing exercises are often ignorant of these five possibilities, which accounts for the fact that such exercises have been condemned by some teachers. With the exception of the last named, each type is appropriate to a particular occasion, and normally in well-trained persons the right type becomes habitual for such occasions. To utilize merely one type only is a serious handicap to healthy living, and the correct usage should be taught in the course of physical education. The lines on which this teaching should be given are indicated in detail in that book, special reference being made to the right use of the diaphragm. Breathing exercises by themselves will rarely, if ever, produce good breathing habits; considerations of posture and the circumstances of the moment must always be taken into account. Right modes of breathing

do not come naturally, even to athletes, in these days particularly, when civilized life militates so often against the acquiring of healthy habits of respiration. Yet they can be easily and quickly learned. Further reference to these practical possibilities falls outside the scope of the present book.

VIII

TESTS FOR RESPIRATORY EFFICIENCY

FROM the foregoing it is obvious that some simple system of testing the efficiency of the respiratory mechanism is desired, and in this connexion reference must be made to the work of Alan Moncrieff (1934 and 1935). The sport of climbing mountains as well as the examination of aviators led to the scientific investigation of the testing possibilities, and a useful list of references is appended by that author to his own work which is embodied in the Special Report Series of the Medical Research Council, no. 198. It must here be premissed, however, that in view of the close association of this system with the circulatory mechanism the practical application of this testing is by no means simple yet, although further research should result soon in the devising of some relatively satisfactory procedure.

Moncrieff employed the following tests: (*a*) measurement of the vital capacity and its component parts by means of a recording spirometer; (*b*) estimation from the records thus obtained of the 'ventilation equivalent for oxygen'; (*c*) estimation of the 'dead space' by calculating the total carbon dioxide expired into the apparatus during the experimental period and hence the percentage in the expired air, as well as the carbon dioxide in the alveoli measured by fractional sampling from the mouthpiece of the spirometer; (*d*) the inspiration–expiration time ratio calculated from the spirometer graph; (*e*) the expiratory force; and (*f*) the endurance power, the last two being estimated by mercury U-tube tests. He groups his results in terms of efficiency as good, fairly good, fair, poor, and bad. A discussion of these results appears in Samson Wright's *Applied Physiology*.

Moncrieff points out that no one single test of respiratory efficiency is adequate by itself. The four aspects of the

respiratory mechanism, namely vital capacity, ventilation, expiratory force, and expiration time appear to represent different anatomical and physiological functions, and one or more of them may be altered in various types of inefficiency. For instance, a muscular young man excelled at the mercury U-tube tests, even though one lung was almost out of action, his compensatory power being very good; only a test of his ventilation power revealed his inefficiency. One lad aged 16 with longstanding bronchiectasis had a vital capacity 92 per cent. of the normal, though he failed completely to blow up the mercury U-tube.

G. E. Beaumont and E. C. Dodds (1934) state that if, except in athletes, the vital capacity is found to be normal, it is unlikely that disease of the lungs is present—a useful practical tip for the medical adviser at physical education centres. Beaumont has also found that the mercury U-tube expiratory force test is not altered much by disease of the lungs, and that the endurance test has little value as a test of respiratory efficiency. Moncrieff considers it clear that the first is a test of neuro-muscular co-ordination, while the latter is closely related to the efficiency of the cardio-vascular system. But both these factors are concerned in the good working of the respiratory system as a whole, and therefore the U-tube test, which is easily performed, is worth retaining in practice. The degree of the prolongation of the respiratory time in relation to respiratory efficiency is a point of some importance as regards the estimation of the possible improvement of this efficiency by gymnastic exercises.

Bruns and Herbst (1932) suggest that prolongation of expiration interferes with the venous return to the heart, leading to venous stagnation in the tissues and some stagnation at the respiratory centres. Increased stimulation of the respiration then ensues, as explained previously, and the resulting conflict may cause dyspnoea. By a process of disciplining the breathing in patients with chronic lung

disease these authors claim to have secured clinical improvement in asthmatic patients, and it may therefore be deduced that the regulation of breathing, either as regards rhythm or style, may have some practical value in physical education. Wall (1928) pointed out that it was not always sufficiently realised that the descent of the diaphragm was the chief cause of expansion of the apex of the lung. Briscoe (1927) reviews the general therapeutical possibilities.

Moncrieff's effort to obtain standards of respiratory efficiency shows both the difficulty and the hopefulness of the problem, and it indicates the great need of further research work. Much more precision could thus be introduced into physical education, and standards of comparison between different methods in respect of their real health values be established. His own method of testing requires very little previous training of the investigators and produces a minimum of discomfort in the persons tested, and that only for five or six minutes. The details of it will be found in his Special Report (1934). It is not yet suitable for use on a large scale in physical education centres, but simplification is likely in the future.

Radiological examination of the heart and lungs in action affords another most valuable line of approach, which will some day be used for physical training as well as for the diagnosis of disease. Samson Wright concludes that 'it is probably fair to say that in the absence of disease of other organs or systems, dyspnoea occurring too early, or limitation in the field of response, would be indicative of inefficiency of the respiratory apparatus. It is probable that the usual tests of cardiac efficiency could be modified to throw light on respiratory function.'

Ordinary observation can be very useful in helping the medical adviser or even a layman to draw preliminary conclusions. The pulmonary ventilation has to be doubled before the ordinary person is aware of any increased rate

and depth of breathing; real discomfort only results when the ventilation has been multiplied four or five times. Other things being equal, persons with a lower vital capacity tend to become out of breath when doing less muscular work than the average person, and with lower degrees of increased breathing.

Training improves the co-ordination of the muscles, eliminates wasteful movements, diminishes the oxygen demand, and involves less expenditure of energy. It has been noted that the mechanical efficiency of an athlete is 25 to 30 per cent., over one-quarter of the total energy output of the body being converted into work, whereas in an untrained person the efficiency is only 20 to 23 per cent., involving him in a greater oxygen consumption and bringing on shortness of breath earlier. The efficiency of the respiratory muscles in the untrained person is also poorer, and so the breathing movements are less easy. Consequently, during training there should be an easily observable improvement in these respects, and so, without mechanical testing of any kind, it is easy in most cases to be satisfied that physical training is doing definite bodily good. It is also obvious that pressure on the diaphragm by a large meal, or failure to use this muscle efficiently, will decrease the vital capacity and impair the respiratory efficiency.

Shallow rapid breathing has been observed in functional nervous disorders, such as neurasthenia, and the psychological side of respiratory efficiency has to be dealt with in some cases. Haldane has attributed this shortness of breath to depression of the respiratory centre which consequently responds more readily to the vagal influences from the lungs, checking the depth of breathing excessively—a condition which may sometimes occur at night. Such enfeebled respiration may be remedied by assumption of the erect position, the diaphragmatic movements being then aided by gravity. It follows that some cases of neurasthenia

will not be benefited by physical training until the underlying cause of the cerebral or psychological weakness has been appropriately treated.

In heart disease with an inadequate circulation the vital capacity is diminished by the congestion of the pulmonary vessels; the patient is still able to do work while it is 70 to 90 per cent. of the normal, but shortness of breath comes on more quickly. His dyspnoea is due to a raised speed of chemical exchanges in the tissues at rest; the diminished vital capacity; an inadequate oxygen supply to the respiratory centre as well as to the other parts of the body; and to the accumulation of carbon dioxide and a diminution in the alkaline reaction of the blood.

NOTE.—For practical instructions how to perform the various tests with regard to the respiratory exchange and other physiological investigations relating to physical education reference may be made to *Human Physiology* by C. G. Douglas and J. G. Priestley (second edition, 1937. Oxford University Press). Galloway (1937) has a useful chapter on the supervision of training and assessment of physical fitness.

IX

CIRCULATORY CHANGES IN EXERCISE

THE blood, heart, and blood-vessels are all affected by muscular activity, but there has been hitherto much too much relative attention given to the second of these in ordinary practice. The function of the circulation is to receive and supply to the active muscles the nutriments and stimulants they require, including oxygen and dextrose; to remove such 'waste products' of activity as carbon dioxide and water; to regulate its constituent parts so as to apportion to different parts of the body an adequate but not an excessive blood-supply for each passing second; to safeguard itself from damage; to effect such modifications as those of the reaction of the blood as will meet all demands; and to promote the subsequent work of recuperation and recreation. Here is obviously a complexity of function which implies a complexity of mechanism, and much more scientific research will be needed to clarify the process in normal and abnormal subjects. Nevertheless, a survey of some of the important points which are known will have a definitely practical import.

Samson Wright in his *Applied Physiology* summarizes the principal circulatory reactions to exercise as follows.

1. The greatly increased venous return is due to the greater depth and frequency of respiration; the vigorous muscular contractions aided by the valves in the veins; and the rise in the capillary and venous pressure.

2. The increased cardiac output on the right side of the heart (by six or more times) is partly effected by the quicker heart-beat and partly by a larger output per minute of blood. The first is caused by nerve impulses from the higher centres to some extent, but probably a much more important factor is the auricular reflex resulting from the

raised venous pressure in the right auricle and increasing the heart-rate in proportion to the rise in the venous return. Another probable factor is the increase in the carbon dioxide tension of the blood, and possibly the relative lack of oxygen, while the rise in temperature of the body generally is also concerned. The larger output of the blood per minute (the stroke volume) may be as much as 200 cubic centimetres; this is attributable to the greater venous filling and the more intense stretching of the heart-muscle fibres at the beginning of the beat (systole).

3. The left side of the heart receives the whole of the output of the right side, and its output is equally increased.

4. The blood distribution in the body is altered so that a greater proportion is sent to the active regions. The arterioles of the splanchnic (internal abdominal) area are constricted at first, the blood being diverted mainly to the muscles and the heart. When the body temperature as a whole rises during violent exercise, the skin arterioles are dilated again to facilitate loss of heat. The skeletal muscles may receive eighteen times their resting blood-flow, the redistribution being effected as follows. (*a*) The vasomotor centre is stimulated by impulses from the higher centres; perhaps reflexly from the active muscles; by the increased carbon dioxide tension; and perhaps by arterial lack of oxygen. The vasomotor nerve-fibres pass chiefly to the splanchnic and skin arterioles. (*b*) Products of the tissue changes dilate the arterioles in the muscles. The internal secretion adrenaline, which is produced in quantity in times of stress, constricts the arterioles with a marked vasomotor supply. The blood-flow to the brain is perhaps increased, since it is dependent to a considerable extent on the raised blood-pressure; the blood-supply to the coronary blood-vessels of the heart is also intensified, and may rise to a height of almost one and a half litres (53 ounces) per minute. In this connexion it may be recalled that there is a much freer coronary circulation in the later years of life, so that

a man at the age of 20 is less fitted to withstand a local coronary obstruction than he will be at the age of 60, and is thus in this detail less well equipped than he will be later in life. The coronary flow increases in proportion to the rate of the cardiac output.

The blood-pressure rises to a relatively smaller extent (from about 120 millimetres of mercury to 160 or 180), and also helps to increase the coronary circulation. This rise of blood-pressure is comparatively small, a fact which indicates how much the peripheral resistance to the blood-flow through the body in exercise is decreased. The dilatation of the vessels to the muscles far exceeds the constriction of the splanchnic vessels and skin which is brought about by adrenalin and by nervous impulses from the vasomotor centre. This explains to some extent the warnings usually given against bathing too soon after a heavy meal; in addition to the retention of the blood in the abdominal cavity, the skin and skeletal muscles are cooled by the water, and the blood-pressure may rise dangerously while the arterial supply of the muscles is kept lower than is needed. Conclusions may also be drawn as regards the inadvisability of cold baths too soon after muscular activity. Stiffness is due to the blood circulation being unable to carry off the excess of fluid in the muscles, and yields to massage or rubbing which improves the blood-flow through the muscles.

5. The capillaries are dilated by the presence in the blood-stream of tissue products of exercise (metabolites); many which have been previously closed open up. This phenomenon does not alter the amount flowing through the muscle in unit time. It decreases the linear velocity of the blood through it, and consequently enables it the better to withdraw oxygen from the blood and to pass into it excess of carbon dioxide. Here is another indication of the importance of securing the right temperature of the environment, during gymnastic exercises, for example.

Collating these facts with those detailed in Chapter VII the bodily reactions to exercise may be summarized as follows. The increased pulmonary ventilation introduces large amounts of fresh air containing oxygen into the lungs and expels carbon dioxide. Larger amounts of oxygen are absorbed by the blood from the lungs. The mixed venous blood arriving at the lungs at rest may have an oxygen-content of 14 cubic centimetres per cent., and take up 5 cubic centimetres per cent.; whereas during hard work it may contain only from 7 to 3 cubic centimetres of oxygen, and therefore take up 12 to 16 cubic centimetres per cent. Thus, the oxygen intake may be increased almost fourfold in strenuous exercise. The cardiac output being simultaneously increased about fourfold or more, the oxygen intake from the lungs may be raised to the amount necessary for muscular exertion. The process of oxidation in the muscles is enhanced, the higher carbon dioxide tension and the raised temperature promoting the active changes in the oxygen-carrying haemoglobin of the blood as well as in its carbon dioxide carrying ability.

Such a collation throws into striking relief the important part played by the respiratory processes in muscular exercise, and emphasizes the need for much more attention to be paid to breathing in physical education. The whole respiratory-circulatory mechanism works to some extent automatically when all its constituent parts are functioning aright as well as being structurally healthy, but the former is less common than the latter. From the point of view of promoting health and endurance it is obviously even more important to concentrate on securing satisfactory working of this mechanism than to devote oneself to improving muscular strength and agility, and the 'daily dozen' exercises must comprehend the adequate measures in this respect for those whose facilities for sports and games are restricted. The increasing sense of exhilaration and fitness thus derived will encourage perseverance in suitably

designed practices, even though they may be lacking in immediate interest, and it must be admitted that some of the older exercises seem dreadfully dull and uninspiring. The cause of physical education can easily be retarded by insisting on their value when no definite increase of a sense of fitness results, and there is no obvious enhancement of joyous and active living.

On the other hand, a better acting heart with fuller ventilation of the lungs, persisting as a habit when the game or gymnastic practice has ended, will be a permanent incentive to further physical training. Nor is it enough to demand merely that the practices be carried on in the open air. From the foregoing it will be clear that it is not a better oxygen supply to the nose and mouth that is the essential point, but rather a better training of the heart and lungs to make the best possible use of the atmospheric environment, whatever its composition, even excluding the psychological considerations which have yet to be dealt with. It is futile to call in psychological devices to redress the physiological wrongs of any form of physical training, but this futility—an attempt to popularize some unpopular, because physiologically imperfect, schemes of training is far too common to-day.

X

THE BLOOD AND TISSUE CHANGES

THE part played by the blood in physical exercise has attained a new significance in recent years owing to the discovery of its 'buffer action', buffer substances being those which hinder changes in the degree of alkalinity or acidity. Acids such as carbonic and lactic acids are formed in the body during muscular activity, while basic radicles such as sodium, potassium, calcium, and magnesium are ingested in ordinary meals, especially in vegetable food, and require to be neutralized; otherwise, death would ensue, for the reaction of the blood is a great factor in health and disease. The blood is slightly more alkaline in the arteries than in the veins, its degree being determined by the relative amounts present of carbonic acid and sodium bicarbonate, and its reaction not being altered by dilution with water—in contradistinction to 'unbuffered' fluids. The blood corpuscles contain also potassium acid phosphate, and so help to maintain the neutrality of the medium in which they circulate. Proteins act as both acid and alkaline buffers.

The lungs deal rapidly with an increased hydrogen-ion content (relative acidity) of the blood due to the presence of an increase in the amounts of carbon dioxide and lactic acid during physical exercise. The kidneys secrete a more acid or more alkaline urine according to the reaction of the blood, and they keep normal the proportion of sodium, potassium, and other crystalloid substances. The intestines eliminate some of the phosphoric acid, as required. In strenuous exercise the blood may have to transport from the muscles to the lungs as much as 4,000 cubic centimetres of carbon dioxide at a time.

Van Slyke (1921) considered that the carriage of this gas

was effected almost entirely by the haemoglobin, but different figures have been recorded by Bock, Field, and Adair (1924), who estimated that 60 per cent. of the amount was conveyed in solution in the plasma, and the question is still open. In any case, were there no buffers present in it, the blood during exercise would become seventy-two times more acid than normal, which would be incompatible with life. So long as there is an oxygen level of 1,800 to 2,000 cubic centimetres (the equivalent of loads of work of 5,000 to 6,000 foot pounds) in the average man, no perceptible amount of lactic acid passes into the blood, but in actively contracting muscles with an inadequate oxygen supply for their task some escapes, and may continue to do so for some minutes after discontinuance of the exercise (Barr and Himwich, 1923). On entry into the blood lactic acid is converted into sodium lactate at the expense of the sodium bicarbonate, and so the 'alkaline reserve' of the blood is lowered. H. A. Salvesen (1928) stated that this lowering might amount to as much as 30 volumes per cent. after a 1,500-metre run.

Lactic acid must, be it remembered, not be regarded only as a waste product, being concerned in the rebuilding of glycogen—as mentioned in Chapter II. It follows that inactive muscles may function during the exercise of others by withdrawing the excess of lactic acid from the blood, and utilizing it to build up reserves for themselves. This explains why an alternating use, for example, of agonist and antagonist muscles can stave off fatigue, and gives one of the reasons why a programme of exercises planned with this in mind can be effective without being fatiguing. There is naturally a limit to the degree to which muscles can take up glycogen thus, as Bock and his colleagues have shown, but it is also obvious that physical training will improve the capacity of muscles to utilize greater quantities of lactic acid, and will thus help in postponing the onset of fatigued states, both general and local. During exercise

lactic acid will accumulate in the muscles, being buffered there by the muscles themselves. After exercise, this buffered lactic acid will be built up again into glycogen, and the local buffer salts be freed to take up more lactic acid from the blood-stream. In very strenuous exercise some of the lactic acid escapes from the body in the urine, and may be found present in it for half an hour to an hour after the activity has ceased.

Physical training increases the alkaline reserve, and it has been shown also that it improves the mechanical efficiency of the muscles, less lactic acid being freed by contraction and more being quickly reconverted into glycogen. This is another factor in the lessened distress which should always accompany training on sound physiological lines, and there is here the possibility of establishing another standard by which different schools of training can be scientifically assessed as regards their physiological value. The 'respiratory quotient' of excess metabolism is the term given to the ratio between the excess carbon dioxide output and the excess oxygen consumption, and may be used possibly in this assessment.

It has also been employed in studying the various kinds of food-stuffs used by muscles during activity. On a diet consisting mainly of fat prolonged exercise reduces the respiratory quotient to about 0·7, indicating that fat is being used as the chief fuel; it is probably transformed into carbohydrate (perhaps in the liver; Best, 1934) and then sent by the blood to the muscles to serve as the source of energy. The body in activity seems to use very much the same food-stuffs as at rest, the dextrose being more rapidly taken up by the muscles from the blood. As indicated elsewhere, proteid can also be broken down for energy producing purposes, but more slowly, and the importance of the accumulation in the blood of nitrogenous by-products interfering with the effective working of the blood itself during exercise has to be borne in mind.

TRANSPORT OF OXYGEN

Arterial blood contains, as a rule, 19·45 per cent. of oxygen volume, and 49·68 of carbon dioxide; the corresponding figures for venous blood are 14·04 and 54·65. J. Barcroft and his colleagues were the pioneers in this study of oxygen circulation, and he pointed out that but for the presence of haemoglobin man's power and activity might never have exceeded that of the lobster. G. A. Harrop (1919) showed that 100 cubic centimetres of arterial blood could be made to yield about 19·5 cubic centimetres of oxygen, of which all but 0·22 to 0·7 was loosely combined with the haemoglobin. The actual amount of haemoglobin and of oxygen capacity varies in different people and in different places; it is obviously one of the points to be studied by a medical adviser to an athletic training centre if questions of breathlessness are concerned. In the capillaries a quantity of about 5·5 cubic centimetres of oxygen is unloaded from each 100 cubic centimetres of blood. This dissociation from haemoglobin is variable, depending on the low pressure of oxygen in the tissues, the presence in them also of a considerable amount of carbon dioxide (and occasionally of lactic acid), and the general body temperature as well as that in the tissues concerned.

RED BLOOD CORPUSCLES

Exercise in healthy subjects increases the number of red blood corpuscles in the blood as well as the percentage of haemoglobin in each unit volume of blood; a similar increase is necessitated when man rises in the air or climbs mountains. Schneider and Havens (1915) showed that the average percentage increase in the first case ranged between 3·2 and 22·8, so this factor in physical education is clearly of the first importance and must be considered seriously by the medical adviser. In terms of numbers of corpuscles the increase during short periods of vigorous exercise ranges

from 200,000 corpuscles per cubic millimetre to 1,180,000, but it is modified by the extent of previous muscular activities and the stage of digestion. Soon after exercise the number of red corpuscles in the blood diminishes again, and the normal is regained in half an hour or a little longer, so that any blood examinations must be made promptly to have any comparative value. This rise in number is part of the compensatory adjustment of the body to effort, increasing the oxygen capacity of 100 cubic centimetres of blood by as much as 1·8 to 2·1 cubic centimetres. For further details in this respect, other than those which are to be mentioned, reference should be made to Schneider's textbook *Physiology of Muscular Activity*.

This increase in the number of corpuscles does not seem to be due to loss of fluid from the blood (Schneider and Havens, 1915), but rather to the utilization of a reserve supply of blood in the splanchnic circulation, a conception reinforced by G. O. Broun (1922–3). Still later, Barcroft and others (1927–9) showed that the spleen in dogs took an active part in this process, mature corpuscles being supplied to the blood-stream. Dill, Talbott, and Edwards (1930), however, found that there was a corpuscular increase in persons from whom the spleen had been removed, so more than one factor must be concerned; probably there is often an increase in the concentration of the blood by the withdrawal of water from it.

P. B. Hawk (1904) found that the increase in red corpuscles diminished during prolonged exercise, and G. O. Broun (1922–3) that the plasma volume of blood increased steadily throughout three or four hours of continued exercise. Again, the red corpuscles have been shown to suffer injury during exercise, and have therefore to be replaced; this is effected, at any rate in part, by the bone marrow. Schneider suggests that this mechanism of replacement may get 'out of training' during prolonged periods without physical exercise, and explain the poor response to athletic

efforts. If this is so, another scientific reason for the 'keep fit' campaign becomes manifest.

Broun has cited this as the probable explanation of the feelings of listlessness and even of malaise which also occur; the subsequent appearance in the blood of young, but not immature, corpuscles brings this stage of depression to an end. The stimulus which excites the bone marrow is perhaps lack of oxygen, and it seems likely that in the untrained man the response is relatively poor compared with that of the trained man, even though no athlete in the ordinary sense. Such a response may be expected during active exercise and also during the succeeding rest period, in both of which there is an increased demand for oxygen by the body. For several days after prolonged strenuous work young red cells continue to appear in the blood, so it would appear that the red marrow requires time to adapt itself to the needs of the body, whether caused by physical or mental activity. In the sedentary and idle person few of these young cells can be found in the blood.

Schneider and Havens (1915) produced experimental evidence that physical fitness, as tested by climbing, was associated with a better functioning red bone marrow. The work of G. O. Broun (1922–3) and others has shown that regular and frequent physical exercise is similarly effective in maintaining an adequate supply of red blood corpuscles. It is believed, though not yet scientifically ascertained, that training gradually increases the percentage of corpuscles, their total mass, and the total volume of blood in the body. It is clear that further research in these respects would have a practical bearing on physical education.

In the sedentary individual prolonged strenuous activity causes an excessive destruction of red corpuscles, and the loss cannot be made good without some delay, thus supporting the important recommendation that the beginning of a very active holiday for such a one should not be strenuous. Failure to note this may result in some degree of

anaemia persisting for several days and even two or three weeks. The same applies to indulgence by sedentary folk in a short but strenuous training period, and to the young as well as to the middle aged. Some preceding regular exercise or mild physical exercising will reduce this delay in adaptation; the spirit may be willing, but the flesh is weak, or at any rate not ready to function perfectly.

WHITE BLOOD CORPUSCLES

The number of white corpuscles (leucocytes) varies during the day; the taking of food, physical exercise, and conditions of asphyxia increase it. Exercise raises the count by 15 to 65 per cent., but the number begins to fall as soon as the exercise is stopped and it may have returned to normal in half an hour. The relative proportions of the different kinds of leucocytes are modified by exercise, though this is more noticeable as a sequel rather than as a concomitant.

So long ago as 1901 Zuntz and Schumberg noted that marching raised the polymorphonuclear leucocyte count by 6 to 11 per cent., while there was a 3 to 17 per cent. decrease in the lymphocyte count. Even higher figures were obtained by Schneider and Havens (1915), who found that there was no definite proportional change immediately after the exertion, but that slowly afterwards for an hour or two the polymorphonuclears increased and the lymphocytes decreased. A. F. Goldberg and M. V. Lepskaia (1926) attributed these changes to the irritation of the blood-forming organs by the products of the accelerated metabolism of nitrogenous substances. F. Gaisböck (1929) found the changes most pronounced at the time when the largest amount of lactic acid was present in the blood-stream; he also showed that the administration of 15 grammes of sodium bicarbonate ten minutes before the exercise delayed the incidence of the leucocytosis, and diminished its intensity. Viale and Di Leo Lira (1927) attribute the leucocytosis

of exercise to an increase of potassium in the blood, and this point is of practical importance from more than one aspect, so further research is necessary.

Gaisböck (1929) has suggested that overtaxing of the person is shown by the leucocytosis not subsiding promptly after exercise, and that in this way training can be standardized to suit the individual needs. The matter is concerned also in the treatment of tuberculous patients by graduated work. H. Ernst and H. Herxheimer (1924) report that well-trained men do not show so pronounced a leucocytosis as do the untrained.

SUGAR IN THE BLOOD

Sugar appears in the blood as glucose, and is found in both the corpuscles and the plasma. All agree that it is the best fuel for muscular work, even though G. Lusk (1928) and Y. Henderson (1925 and 1928) maintain that fat is also a source of energy in athletes. It operates by remedying the loss of lactic acid, partly oxidized in the muscles and partly eliminated in the urine. The sugar-content of the blood is fairly regular, except after strenuous exercise; it rises to about 0·18 per cent. after a meal rich in sugar, but the liver, muscles, and white blood corpuscles store it in the form of glycogen. When the blood-content falls below the normal of about 0·08 per cent. these storage depots are called upon to yield up their reserve.

Mild exercise does not affect the measurable sugar-content appreciably, this mechanism operating smoothly, but in more active pursuits the sugar-content increases, especially if associated with emotional stress (H. T. Edwards, T. K. Richards, and D. B. Dill, 1931). The effects of physical exertion on the blood-sugar level have also been studied by C. Bruusgaard (1929), who found that in athletes there was a constant excess of sugar after violent exercise lasting thirty-five or forty minutes. It was less pronounced in the training period than in contests. If the exercise lasted

three hours there was a definite fall in the sugar-content, but since this depends on the varying reserves of sugar available in different persons it is not surprising that the results of measurements of this fall vary considerably.

Exhaustion after strenuous exertion is, however, definitely associated with a depleted sugar-content of the blood and Schneider cites in his book (*Physiology of Muscular Activity*) some valuable investigations on Marathon runners in America. One deduction of importance relates to the good results obtained in 1925 from training the competitors on a diet moderately rich in carbohydrates, sugar being also supplied during the race, at the end of which the blood-sugar figure was found to be nearly normal while the physical condition was much better than was the case in the comparable race in the previous year. In 1924 the prostration noted resembled that of insulin shock, and it may be added that the signs and symptoms of this are in order: hunger pains; a feeling of weakness, faintness, and fatigue; sweating and tremulousness, with sometimes pallor or flushing; acute distress with mental disturbances and loss of emotional control; and unconsciousness. The probability that physical exhaustion due to exercise is related to a low sugar-content in the blood is thus very great, and the suggestion has been made that it would be as well to provide ample sugar in the blood and tissues by giving sugar half an hour or rather more before any prolonged violent exertion has to be taken.

PHOSPHATES

Food rich in phosphates has been commended to physical as well as to brain workers, the idea being that these salts are concerned immediately in forming lactic acid. A 'phosphated sugar' seems to be more effective than ordinary glucose (Embden and Habs, 1926). Moreover, inorganic phosphates are liberated as a result of muscular activity,

and are eliminated in the urine. They must therefore be restored to the body.

At first after muscular activity the inorganic phosphorus content of the blood is high, but it then falls below the normal, the muscles taking up the blood phosphates to manufacture the 'phosphated sugar' and creatine phosphate (phosphagen) for their recuperative needs. Obviously, a shortage of phosphates in the blood would constitute a grave physical handicap. R. E. Havard and G. A. Reay (1926) have shown that after exercise the blood phosphates in the trained man do not fall so low as in the untrained one, and it has been suggested that the muscles can be taught to store up an increased amount of 'phosphated sugar'. This may well be one of the factors in the process of 'getting fit'. N. P. Riabuschinsky (1930) has found that normal young adults can be enabled to work much better by taking sodium phosphate in amounts which approximately double the daily phosphorus intake. The tonic effect of hypophosphite preparations in medical practice will be recalled in this connexion.

XI

GASES IN BLOOD AND TISSUES

THE absorption and discharge in the lungs of gases by the blood depend on the thickness and other properties of the membrane lining the alveoli or terminations of the smallest bronchioles; differences in the partial pressures of the gases; the velocity of the blood-flow; and conditions in the blood. The alveolar membrane differs in thickness in different persons and in permeability; some families seem to have as a familial characteristic thicker membranes than others do (M. Krogh, 1915), and are consequently less able to meet respiratory stresses than others—a fact of occasional importance, possibly, to the medical adviser. During sedentary occupations parts of the lungs are shut off from the tidal air. The whole alveolar surface has been estimated as representing on an average about 100 square metres (110 square yards), and one-fifth to one-eighth of this area is probably sufficient to maintain the normal respiratory exchange during rest. Exercises of speed rapidly bring the exposure of the pulmonary membrane to the maximum, assuming that there are no faulty habits of breathing or diseased areas of lung tissue.

It is generally thought that oxygen passes from the air into the blood by a process of diffusion, though some physiologists have suggested that this gas may be secreted by the lungs. At rest the arterial blood is nearly 95 per cent. and the venous blood 65–80 per cent. saturated with oxygen; the partial pressure of this gas in the alveolar air ranges from 93 to 107 millimetres of mercury. The blood never becomes fully saturated with oxygen in the lungs. The flow through the lungs governs largely the supply of oxygen to the body, and this rate is set by the action of the right ventricle of the heart, which may be hindered by

disease in some cases from performing its function adequately, when shortness of breath ensues. The exchange of gases in the lungs depends also on the number of red corpuscles and the amount of haemoglobin in the blood, as well as on its degree of alkalinity. Some persons cannot absorb more than 2,000 cubic centimetres of oxygen a minute. Himwich and Loebel (1927) find that during exertion in ill or debilitated persons the volume of oxygen diffusing through the alveolar membrane is insufficient to saturate the haemoglobin; they think that this may constitute a limiting factor in exercise, and may help to explain the inability of ill persons to undergo exertion.

The arterial blood range of carbon dioxide content is from 50 to 53 volumes per cent., while the venous blood range is from 54 to 60; only 2·9 are present in simple solution, so that the greater part of the gas which is given off in the lungs results from chemical dissociation, about 70 per cent. being held by the haemoglobin, just over 20 per cent. by cell phosphates, and less still by the plasma protein and bicarbonate. Diffusion is the sole means by which carbon dioxide is given off, and during physical exertion a quantity up to 4,000 cubic centimetres a minute has to be freed thus. The breathing is regulated at a level to wash out of the body all that is set free. The carbon dioxide capacity of the plasma may be taken as an indicator of the alkaline reserve of the body.

Transfer of the oxygen from the red corpuscles to the muscles involves the chemical break-down of the oxyhaemoglobin into oxygen and haemoglobin, and the diffusion of the gas to the fibres through the capillary wall and the lymph. For details about these processes reference may be made to the text-books of Samson Wright, Bainbridge, Schneider, and others. The reaction of the blood as well as the temperature in the body tissues are important regulators. During strenuous activity the muscles may take up ten to twenty times more oxygen than when at rest, all

the muscle capillaries opening to their widest extent for the purpose. Each capillary has to supply oxygen to about twelve times its own volume of muscle. For some time after the end of contraction the muscle continues to use relatively more oxygen than during rest—a fact which has a practical bearing on the promotion of recovery after strenuous exercise.

Carbon dioxide is only produced in the muscles during the period of recovery, never during contraction, and is therefore an indication of the amount of lactic acid oxidized in the process of restoring energy. The resynthesis of glycogen from lactic acid begins as soon as the latter is set free, and in moderate continuous work there is a balance between the building up and the breaking down processes causing what is known as the 'steady state'. The carbon dioxide which is set free unites with the available water in the muscles and blood-vessels to form carbonic acid, which unites with the 'buffers' of the haemoglobin and the acid potassium phosphates in the corpuscles which are thus enabled to carry considerable quantities of carbon dioxide from the muscles to the lungs. Similar action occurs in the case of the sodium protein of the blood plasma.

Oxyhaemoglobin is said to be about seventy times as acid as reduced haemoglobin, and so the transfer of oxygen from the blood in the capillaries to the muscle-tissues, &c., prepares the haemoglobin for its other duty of absorbing carbon dioxide—the whole being an illustration of the neat adaptation of body chemistry and physics to the various functions which the tissues have to fulfil. Such apparently remote considerations are very important in considering the requirements of physical education, and explain in some measure why the empiricism which has been so common in the past in designing training programmes must now give place to a more scientific approach if practical advantages are to result. In Bainbridge's *Physiology of Muscular Exercise* (revised by A. V. Bock and D. B. Dill) it is stated:

'In strenuous exercise each litre of blood must transport from tissues to lungs as much as 600 cubic centimetres of oxygen per minute. Assuming a blood-volume of five litres and complete circulation of the blood in twelve seconds, it follows that each litre passing the lungs delivers 120 cubic centimetres of carbon dioxide.'

The maximum transport demands the assistance of a greatly increased blood-flow through the muscles, another important factor in physical training, to which attention will be given in the next chapter. There seems to be little difficulty, other than the laboured breathing, in eliminating almost any quantity of carbon dioxide from the body, because this gas is so very easily absorbed by the fluids concerned. This again recalls attention to the necessity of doing everything possible to secure the optimal working of the respiratory system in exercise, and renders it a curious fact that in practice this side of physical training has been so little considered. Good breathing habits are seen to be of immense significance in preserving health ordinarily as well as in physical recreative work, and it must again be emphasized that the adoption of a few breathing exercises is a very inadequate measure since such exercises are usually very unscientifically devised from the point of view of tissue exchanges and that of securing sound respiratory habits which will proceed automatically. What is necessary—indeed, urgently desired—is the working out in principle and in practice of a scheme of adaptation of breathing activities to muscular activities. The introduction of such a broad scheme into recreational activities generally would vitalize the nation, promote its health, and reduce the incidence of disease.

The prevalent bad habit of holding the breath during such strenuous work as that entailed by a tug-of-war may be cited as an example. The tissue exchanges are eventually impeded beyond the tolerance of the body, and collapse ensues. Such collapse could be delayed by sound breathing

habits, and these would be further beneficial in overcoming other stresses such as are met in daily life, even those of emotional origin. 'Take a deep breath' or 'count up to sixty' before replying to an embarrassing or difficult question are suggestions which have a physiological value as well as a psychological or a common-sense one. Similarly, when a long period of heavy work has to be undertaken, the man who will shoulder the burden most effectively is the one who has acquired such useful breathing habits—a fact which can easily be observed in daily life.

The medical adviser to a physical training institution has a much wider scope for usefulness to the community than is apparent at first sight, but he must understand the underlying scientific basis of his work as well as realize to what other activities of life it is applicable. Something of this was realized by the Greeks in classical times, and it is not surprising that the advances of modern science have brought the question again to the front, with new possibilities of securing more vigorous, disciplined, and healthy living, with a correspondingly greater joy in life. This is to be done by promoting a renaissance now of the two great Greek conceptions (Newman, 1932), namely rationalism and naturalism. The naturalistic revolt against the physical, mental, and spiritual deformation consequent on modern industrialism must be guided and controlled by an inspired rationalism. The scientist must take the lead, and turn the present chaos of conflicting speculations about physical education into a cosmos of orderly teaching and practice.

XII

THE HEART IN MUSCULAR ACTIVITIES

THREE phases of cardiac action must be defined: a period of atrial systole or contraction; a period of ventricular contraction which follows the former immediately; and a period of diastole or rest (*Cunningham's Text-book of Anatomy*, seventh edition, 1937). During relaxation, the expansion of the chambers of the heart is aided by the respiratory movements of the thorax; hence, breathing movements and exercises have an important bearing on cardiac activity—a fact which is usually overlooked, to the detriment of many persons both young and old. In addition to the rhythmical contractile power of heart-muscle, an important factor in the regulation of the heart-beat is the operating of the special cardiac nervous mechanism. Details of these agencies can be found in up-to-date anatomical and physiological text-books.

In his *Manual of Human Physiology* (fourth edition, 1935) Sir Leonard Hill summarizes simply the whole process of the circulation as follows. (1) The heart is an intermittent pump. (2) The great arteries are essentially elastic tubes. (3) The small arteries are essentially muscular tubes. (4) Since the blood cannot escape easily through the small arteries, the large arteries are kept distended by the systoles of the heart. (5) The elasticity of the distended large arteries continues to force the blood on through the small arteries during the diastoles of the heart. Thus an intermittent flow from the heart is converted into a continuous flow through the capillaries. (6) The force of the heart is mostly expended in driving the blood through the small arteries and, owing to friction, is partly dissipated into heat. The blood-pressure is highest in the arteries, much less in the capillaries, and least in the veins. (7) The blood is returned from the

veins to the heart mainly by the action of the muscles, by constant change of posture, and by the aid of the respiratory pump (all factors of the greatest importance in physical recreation!). (8) The veins are wider than the arteries; they are provided with valves, but are not very muscular nor very elastic. (9) The capillaries have exceedingly thin walls through which the exchange between the blood and the tissue cells takes place.

The way in which the heart does its work is not well understood, and Yandell Henderson (*Lancet*, vol. ii, 1925) described two conceptions; the first being that the amplitude of the heart-beat (stroke volume or systolic discharge) was variable, and the second that the cardiac output remained regular both in rest and exertion while the composition of the blood as well as the minute-volume altered. The increased demand for oxygen during physical activity may be met by accelerated frequency of the heart-beat, enhanced removal of oxygen from the blood, or augmentation of the heart output per beat, or by some combination of these. A. V. Hill, C. N. H. Long, and H. Lupton (1924–5) proved that for an athlete to absorb 4,000 cubic centimetres (140 ounces) of oxygen a minute there must be a heart output figure of not less than 30 to 40 litres (1,050 to 1,450 ounces) a minute, and that this with a pulse-rate of 180 demands an output at each beat of 167 to 222 cubic centimetres (6 to 7·7 ounces). This enormous figure gives some indication of the amazing adaptability of the trained heart to great calls upon it, and explains the size of the aorta which has to carry away such a volume without any delay. It is obvious that the value of gymnastic exercises depends in considerable measure on their ability to train the heart.

It is generally believed that the pericardial sheath of connective tissue round the heart has a protective function, limiting excessive distension of the chambers of the heart and possibly preventing it from becoming fixed to adjacent

structures. It has been calculated that the maximal volume of the pericardial sac is 700 cubic centimetres (24½ ounces), and that 233 cubic centimetres (8 ounces) is the maximal volume which either ventricle could reach. The ventricles do not completely empty at the end of their contraction, and therefore the maximal stroke volume never quite reaches this figure. Moreover, it seems that the size of the heart is correlated with the body-weight and size, and is therefore variable for humanity as a whole. During rest it pumps at each beat 0·6 to 0·8 cubic centimetre per pound of body-weight.

Investigations by Patterson and Starling (1914) and by Patterson, Piper, and Starling (1914) showed that the metabolism and energy of the contraction of heart-muscle depend on the original length of the cardiac muscle-fibres, and that consequently the output can be increased within wide limits in direct proportion to the inflow of blood. The ventricular output depends on the degree of ventricular filling during diastole, and this in turn upon the venous pressure which rises rapidly during exercise and is affected by the negative pressure within the thoracic cavity. There is probably no such cardiac tonus as was previously mentioned in the case of the skeletal muscles; W. J. Meek (1927) reviews the literature on this point which has been much disputed, and concludes that there is as yet no convincing evidence of the existence of any sustained contraction of the heart-muscle fibres persisting through diastole.

The thick-muscled heart of the athlete does not stretch so much under strain as does that of the untrained person. Furthermore, the tired heart of an untrained man cannot contract so effectively during heavy work, and consequently becomes dilated and stretched. Yandell Henderson and others (1927) have reported on the efficiency of the heart and the significance of rapid and slow pulse-rates, while J. Hefter and R. Judelowitsch (1928) have discussed the phenomena of fatigue in manual and sedentary workers.

With the incidence of fatigue, especially in poorly nourished hearts, the volume of blood expelled at each beat diminishes.

Henderson, Haggard, and Dolley (1927) recorded evidence that in men who took no regular exercise this volume remained approximately the same in muscular activity as in rest; in other words that there was but little power of adjustment. In the case of those who took habitually such moderate exercise as golf or rapid walking there was some increase of stroke volume, but not so much as could be detected in those who ran, rowed, or played football. Even more convincing evidence of this kind has been adduced by A. V. Bock and others (1928); De Mar, the Marathon runner, kept in a state of physical training continuously for about twenty years, and had a much larger stroke volume while at rest than the non-athlete. The increase in volume in his case during intense muscular activity was definitely less than in less athletic persons; in other words he could achieve his objectives with lesser call upon the resources of his heart.

As regards the minute-volume (the output of the heart per beat multiplied by the pulse-rate) Grollman (1928–31) has found that in adults the figure of about 4 litres a minute during rest remains about the same whether the subject is awake or asleep, is increased by emotional states, but is unaffected by posture, the effects of gravity in man being thus fully compensated in normal conditions. It may be increased by taking food, and by the ingestion of large quantities of fluid. As has been mentioned, it is much increased by strenuous exercise, which favours the return of venous blood to the heart. Grollman found that in mild exercise the output per minute was independent of the oxygen consumption when different groups of muscles were used in turn.

It might be concluded from this and similar observations that the so-called rhythmic movements much in vogue in certain schools will not be so valuable in 'tuning up' the

heart as more strenuous exercises, since they involve less muscular activity, though they may have advantages of a different order. The question is of great practical significance; it indicates that the main objectives from the physiological point of view must be borne in mind when devising any programme or system of training, and that such 'rhythmic' work should be balanced by more arduous work in the whole training scheme if the best results are to be obtained. The psychological disadvantages of a monotonous programme must also be remembered in this connexion.

THE PULSE-RATE

The rate of the heart-beat alone is not a reliable index of the minute-volume of the circulation, especially in comparing various persons each of whom has his individual coefficient (Benedict). This rate is affected by postural changes, emotional factors, and metabolic activities such as those accompanying digestion and absorption of food, independently of muscular activity. Estimation of the resting pulse-rate gives an individual value, and great care must be taken in generalizing from even a large group of individual studies. The word 'normal' is even less applicable in these studies than in others, and departures from the normal have only slight importance from the point of view of a medical adviser, unless very marked and associated with other clinical phenomena. A discussion of this point will be found in Schneider's text-book, *Physiology of Muscular Activity*. It has long been known, however, that the pulse-rate of athletic persons is slower than the average for mankind, and the same applies in the case of healthy persons compared with those who are suffering from chronic fatigue or some debilitating illness. The fact that such a difference has practical individual connotations should not lead to its being over-emphasized as a means of defining standards of physical health.

Men who are physically fit show a smaller difference between the recumbent and standing heart-rates than do those who are not fit—a fact which relates to the dizziness experienced by some on getting out of bed in the morning, as well as to those who get up for the first time after having been confined to bed by illness. A. H. Turner (1927, 1929, and 1930) states that the best standing reaction for young women is a pulse-rate which rises by about ten beats from a recumbent rate of fifty to sixty. Signs of maladjustment of the heart or of the vasomotor system comprise a high rate during recumbency and a large increase when rising to the vertical position, or a continuous increase in the rate during standing prolonged for about fifteen minutes. An abrupt slowing of the pulse-rate after adjustment has been effected often precedes or accompanies acute dizziness or fainting.

The pulse-rate rises rapidly at the beginning of exercise, and may take some time in becoming stabilized (Bowen, 1904). The rise is less if emotional factors are absent, and if the load of work is only gradually increased. It is also related to the amount of oxygen consumption, as was shown by A. V. Bock and his colleagues (1928). It was revealed by study of various types of person that the frequency of the heart-beat maintains an approximately linear relationship with the demands of physical work up to a certain load which varies in different subjects; beyond this point the heart responds less actively than at first, and with still further increases the point is approached when this form of cardiac response can develop no more. R. D. Gillespie (1924) found that mental calculations lasting from a few seconds up to three or four minutes accelerate the pulse-rate by five to twenty beats a minute, independently of emotional factors. The increased frequency is generally greater in combined mental and muscular work than in either independently.

Training, however, decreases these rises in the pulse-rate, and a steady state is reached more quickly. Herein

lies part of the explanation of the fact, of which so much is being made at present, that more physical exercise introduced into the school curriculum promotes a better quality of brain work, even if indoor gymnastic work is the form of exercise employed. The old phrase 'a good walk will blow away the cobwebs of mental or emotional stress', with its implication that the oxygen in the air or the stimulation of the skin by air currents (Leonard Hill's investigation) was the essential factor, now seems to have a wider and even more important significance, the effect on the heart action having to be borne in mind.

In short, whatever the way of training the heart to undertake greater loads of work, the cardiac efficiency for all kinds of work is enhanced, and the objective of training, termed 'Endurance' by Baden-Powell in *Scouting for Boys* so long ago as 1907, is seen to be primarily though not entirely a pulmo-cardiac function, and to be therefore the prime objective in physical education on whatever lines it is undertaken. Schemes of physical training must be judged primarily according to their value in this respect, and it is sad to have to add that very few of the newer planners of schemes seem to have considered this point at all! Research, and still more research, is urgently necessary before any such dogmatism as is current to-day in physical education circles about various modes of training can be justified, and the medical practitioner has a great part to play.

The pulse-rate, invariably high at the moment of stopping active exercise, falls at first rapidly and then more slowly until the pre-exercise rate is reached or passed. W. P. Bowen (1904) distinguished a primary fall, a 'plateau', and then a further fall. O. S. Lowsley (1911) detected occasionally a secondary rise after the primary fall, which might be a reflex due to a low blood-pressure. The return to the normal is quicker in the trained and healthy than in untrained or unhealthy persons. The time taken in this is

also affected by the amount of work done, the load that has been carried, the physical condition of the worker, and the time when the last meal was taken. R. J. Lythgoe and J. R. Pereira (1925) recorded this fall and the decline in oxygen consumption after exercise, showing that the first was more gradual than the second, there being a great diminution in the intake of oxygen in the first half-minute probably owing to the circulatory changes induced by the change-over from exertion to rest, and by no means altogether desirable from the point of view of the needs of the heart and body. There is an immediate decrease in the output of the heart per beat at the end of exercise. The average increase in the heart-rate after moderate, rapid, and exhausting exercise has been found to be respectively 26, 33·5, and 54 beats per minute. Lowsley found that the rate returned to normal within about half an hour after the first form of exercise and one hour after rapid exercise, while the third form entailed a period of three and a half hours before normality was regained.

As the result of emotional stimuli, there may be acceleration of the heart-beat before the exercise is started, associated with increase in the cardiac output and a rise in blood-pressure. S. W. Britton and his colleagues (1930) reported that quick changes in the heart-rate were brought about only by the vagal, sympathetic, and adrenomedullary nervous mechanisms; any one of these might be eliminated without interfering with the emotional acceleration of the cardiac action, while the removal of any two markedly reduced the acceleratory ability. Without such anticipatory acceleration, exercise quickens the beat immediately, the heart cycles decreasing in length at once. So quick a response eliminates the possibility of there being any chemical factor, and nerve considerations are alone concerned. H. S. Gasser and W. J. Meek (1914) distinguish two types of acceleration, one immediate and the other prolonged, the various factors being a decrease in vagal tone, stimulation of the

accelerator centre, a secretion of adrenalin, and an increase in the temperature of the blood.

Without going much farther into the problems which arise, it may be mentioned that Bainbridge (1915) attached great importance to the rise in venous blood-pressure in the thorax generally and the right auricle, which originated a nervous reflex, a theory later endorsed by G. V. Anrep and H. N. Segall (1926), but doubted by A. C. De Graff and J. Sands (1925). Lack of oxygen stimulating the secretion of adrenalin was indicated by the researches of Gasser and Meek (1914), but disputed by G. N. Stewart and J. M. Rogoff (1922). The thyroid secretion was suggested as an active agent by W. B. Cannon and P. E. Smith (1922), but it is known that half an hour or more must elapse before this becomes effective, in sharp contrast with the promptness of action of secretions derived from the suprarenal glands and the liver. W. B. Cannon and Z. M. Bacq (1931) attribute importance to a hormone produced by sympathetic nerve stimulation of smooth muscle (sympathin). The action of the rise in blood temperature cannot be considerable, although a high environmental temperature is known to accelerate the heart-rate very much. It is doubtful whether a lack of oxygen or an excess of carbon dioxide has any direct effect on the pulse-rate in man. These researches, though indecisive, have a practical import on questions of training, and further investigations will be of much more than theoretical interest.

XIII

ARTERIES, VEINS, AND CAPILLARIES

THE rate of the circulation through the body varies inversely as the total cross-section of the vascular bed in any part; it is 0·8 to 1 metre a second in the aorta and in its larger branches, considerably less in the arterioles, and only about 0·5 to 1 millimetre a second in the capillaries. It increases steadily in the veins as they approach the heart. The velocity of the pulse wave is considerably more rapid than that of the blood.

The elasticity of the arteries decreases with advancing age; thus, with the same cardiac output the blood-pressure is raised more during systole in older persons than in the young—a fact which has obvious practical implications in prescribing exercises and recreative activities for different ages. It may be generalized that rhythmic activities which do not demand so much muscular effort as forcible exercises may be commendable to older persons who desire to *keep* fit as contrasted with younger ones whose aim should be to *get* fit. By virtue of this elasticity the arteries convert the intermittent output of blood from the heart into a steady flow. The smaller arteries and the arterioles regulate locally the amount of the flow according to the changing needs of the tissues supplied; their muscle-fibres are innervated by two types of nerve-fibres, vasoconstrictors and vasodilators. C. J. Wiggers (1921) points out that they are the chief physiological determinants of the peripheral blood resistance. They play an important part during the so-called suppling exercises which are sometimes employed before strenuous gymnastics.

The venous return of blood to the heart depends largely on the following factors (Samson Wright, 1936). The contractions of the skeletal muscles squeeze the blood out of

their veins towards the heart; this process is assisted by the presence of valves in the veins as well as by the probable fact that the veins are also contractile. Each inspiratory movement increases the negative pressure in the pleural cavity and aspirates blood towards the heart. The descending diaphragm raises the intra-abdominal pressure and squeezes blood out of the splanchnic (intestinal, &c.) veins. A slight positive pressure (6 to 10 millimetres of mercury) in the veins and capillaries propels blood towards the heart; relaxation of the arterioles in any part of the body raises the local capillary pressure and so aids the venous return. The force of gravity assists the venous return from parts of the body above the heart, but greatly hinders the return from the lower parts—one of the reasons why the recumbent position is assumed in cases of exhaustion or failing heart action. A decrease in the blood-volume, for example after haemorrhage, diminishes the venous return, as also does dilatation and increased patency of the capillaries by accommodating an additional amount of blood. There is little doubt now but that the veins are innervated and their calibre is regulated in the same way as are the arterioles. The venous pressure is increased during physical exercise because the raised arterial pressure is transmitted through the very dilated arterioles of the active muscles. Excessive deep breathing may lower the venous pressure slightly.

The various factors in the maintenance and the modifications of the tone of the arteries are indicated in Fig. 5.

The peripheral resistance to the blood-flow is found chiefly in the tonically contracted arterioles of the splanchnic area and the skin, and to a less extent in the capillaries. When the last named in the muscles dilate during muscular action, others elsewhere in the body (the splanchnic region, for example) become constricted so as to compensate accordingly. In histamine poisoning all the capillaries dilate; the venous return falls, the output of the heart diminishes, and the brain and tissues generally suffer severely from

oxygen deficiency owing to their impaired blood-supply. This sequence occurs less markedly, but for the same

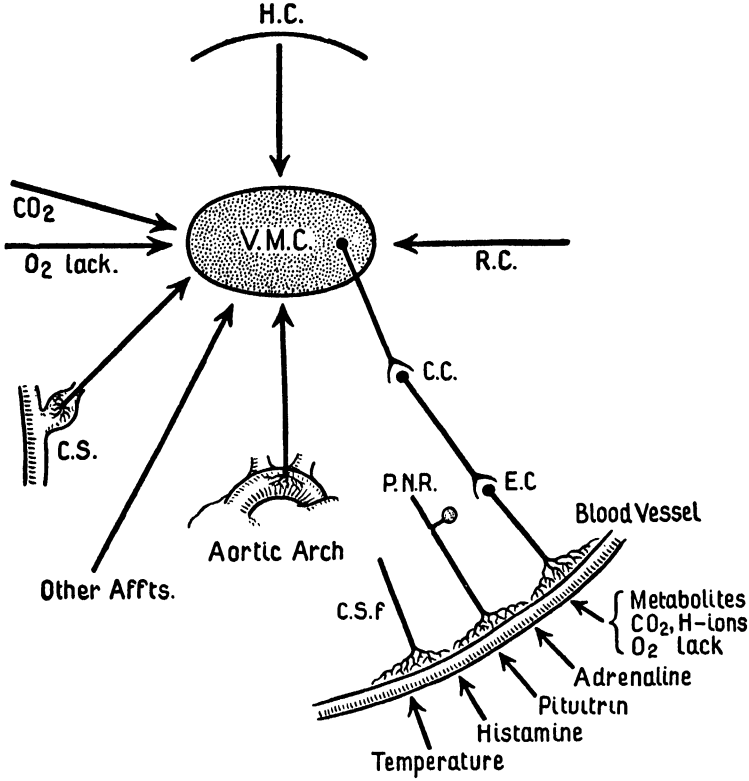

FIG. 5. REGULATION OF ARTERIAL TONE. (By permission from Samson Wright's *Applied Physiology*.)

V.M.C. = Vasomotor centre; R.C. = Irradiation from respiratory centre; C.S. = Carotid sinus; C.C. and E.C. = Connector and excitor cells of sympathetic nervous system; P.N.R. = Posterior nerve root dilator fibres; C.S.F. = Cranial or sacral autonomic dilator fibres.

reasons, when exercise is taken too soon after a meal because the intestinal arterioles are themselves actively at work, and cannot be constricted without serious consequences. Some have believed that this factor is involved in the occurrence of cramp when sea bathing follows too quickly after a meal. When tissues are injured a histamine-like substance appears

to be passed into the circulation, and capillary dilatation follows, with consequent local arteriolar dilatation (Lewis, 1924). The effects of heat, light, and cold on the body have been similarly explained on these lines.

The frictional resistance encountered by the blood passing the blood-vessels depends on its viscosity, the size of the lumen of the tube, and the velocity of its flow. This explains why restoration of the blood-volume (after haemorrhage, for example) is so much more quickly effected by blood transfusion or the intravenous injection of gum-saline rather than of ordinary saline solution. Dehydration of the body by too rapid withdrawal of water by excessive perspiration in a hot atmosphere during exercise throws a strain on the circulatory mechanism, and thirst develops as an indication of the need for fluid administration. It may be noted here, however, that what the body has lost is not pure water but water containing salts, and that these have also to be supplied; failure to do this is signified by the occurrence of cramping pains during the next twenty-four hours.

The vasomotor nerve centre is situated on the floor of the fourth ventricle of the brain, and is continually sending out vasoconstrictor impulses to regulate the tone of the arterioles, and probably also of the capillaries and veins. It is thrown into activity by the chemical and gaseous contents of the blood and by nerve impulses reaching it from all parts of the body. It is very closely related functionally to the respiratory centre. The vasodilator centre is not so definitely localized, and acts only intermittently, possibly a pure reflex mechanism. (For further details see *Applied Physiology*.)

ARTERIAL BLOOD-PRESSURE

The systolic blood-pressure indicates the heart energy expended during systole, while the diastolic denotes the pressure during diastole; the difference between the two is

termed the pulse-pressure. The diastolic pressure is of equally great importance to the systolic pressure, since it represents a measure of the peripheral resistance to the circulation of the blood, and is therefore an index of vasomotor tone. It indicates the work which the heart has to do before any blood can be expelled from it, and is normally about three-quarters of the systolic pressure. If the pulse-pressure can be taken as an index of the stroke volume of the heart, multiplying it by the pulse-rate will give an index of the minute volume of the circulation.

Thus, we have a simple way of comparing the output of the heart per minute in different forms of exercise and of comparing the demands on the heart made by different kinds of work. We can, moreover, estimate to some extent the way in which a given person is responding to a special line of training; and make a much more scientific reply as regards his fitness than has hitherto been the case. Too many favourable reports as regards one or other system of physical training have been based solely on the personal feelings of the teacher or the pupil, and the time has come to insist on proper scientific standards of comparison such as this minute volume estimation would appear to afford.

A huge literature has grown up on the question of blood-pressure in health and disease, and only a few of the important points can be dealt with here. Reference may be made for further details to Samson Wright's *Applied Physiology*. 'The desired constancy of blood-pressure is attained mainly reflexly by the aortic and sinus nerves ("buffer nerves"), principally by means of the variable tonic inhibitory influence which they exert on the cardiac and vasomotor centres and on adrenalin secretion. A rise of blood-pressure at rest increases their inhibitory activity; a fall of blood-pressure lessens it, and may also bring into action pressor fibres which are believed to arise from the aorta and carotid sinuses.'

P. Stocks and M. N. Karn (1924) report that the mean systolic pressure rises uniformly with age up to 11; during adolescence the gradient is increased. The uniform adult level is reached at the age of about 18 (subject to conditions of health, heavy or light employment, &c.), and then no further tendency to rise is noticeable usually until the age of 35 or 40. The diastolic pressure rises more or less uniformly until adolescence, and then more slowly until 17, after which it rapidly reaches its normal maximum at about 20. The pulse-pressure rises, therefore, uniformly until the age of 15, and then more rapidly to 16 or 18; it then falls to its original level at about the age of 20, after which it slowly increases until 40.

These considerations are of the utmost importance in devising schemes of physical training for the young. Without going into details at this point it may be remarked that in many cases there is inadequate active muscular exercise in these earlier years of life, and the devising of schemes of rhythmic movements with their relatively monotonous repetitions will only lead their promotors to ultimate disappointment, since they appear to be advocating methods which do not correspond to the needs of the developing heart and circulation. This is not intended as a general condemnation, because circumstances (of environment as well as of personal physique) alter cases. But it is high time that the needs of the body and mind were clearly stated on a scientific basis by those who dare to advise the nation as to physical education.

Stocks and Karn conclude from their observations that the heart is performing more work per unity weight of cardiac muscle during adolescence than at any preceding or subsequent period of life up to the age of 40. Admitting the necessity of avoiding strain, it is quite obvious that the training of the cardio-respiratory system as well as of the musculature is of paramount importance at this time and, as Professor Cathcart has pointed out again and again, the adaptability of the body and mind in adolescence is amazing.

If we can judge by the history of training in classical and medieval times, as well as in the beginnings of the industrial age, much more physical training of the body to-day in these early years would greatly benefit the health and endurance of the nation as a whole. The medical practitioner is often too cautious and inclined to advocate rest, relying on a false analogy with older subjects who are enfeebled by disease or faulty conditions of living. In cases of doubt individual supervision is undoubtedly necessary, but the morbid consequences of physical under-development are too often confused with the signs of malnutrition or of disease, and modern research to establish criteria in all these respects is urgently necessary, especially in the case of the first one. Failure to secure full physical development in adolescence and early adult life is probably one of the greatest national dangers of to-day in Great Britain, though not in certain other countries.

At this point an extract from Newman's most valuable book *The Rise of Preventive Medicine* would seem to be justifiable. He indicates the scientific basis of Greek education, and shows the relation of the physical part of it to the intellectual and ethical objectives. Such a consideration is most necessary if the present campaign in Great Britain for physical health is to succeed.

'It has been said, and I think truly, that education and culture made Greece. But we must notice that it was not what we in these days describe as education and culture. There was no national system of education in Greece in the generative period of the fifth century, and little or nothing of the comfort, luxury, and amenity of the culture similar to that which we have in England to-day. There was indeed education, and its principles were subsequently interpreted and glorified by Socrates, Plato, and Aristotle, but it was not national in extent or in administration, not compulsory, not universal, not uniform, not rate-aided, not literary or technical. *It was a nurture*, a nurture in character of body and mind, which was destined to make good citizens and reliable soldiers.'

The similarity of this to the present campaign is striking,

but there are also some notable differences, arising out of the changes in national and international outlook.

'Athens was a city-state, and that is perhaps its chief legacy, for out of that came its literature and art, its science and energy. These cities were not like our cities, monotonous collections of industrial population herded together for commercial purpose and jointly forming the bulk of a nation. The city was a *state*; it was composed of cultivators of the soil; it was a centre of nurture, discipline, and religion, where the people "set up house together"; and it was a fortress to be defended, and all its men were, as patriots, to be always ready to fight. The Greeks had learned that, though love of country may make men brave, it is only by organization that they can be made strong. They organized with a loose hand and as occasion and opportunity demanded; and as their city was narrowly circumscribed its population must be kept within bounds.

'In the city-state of Athens school education in the first three-quarters of the fifth century was available from 6 to 14 years of age. It was for boys only, and even so not for the children of slaves and serfs. It included *letters* (reading, writing, and dictation), *music* (the lyre and singing), and *gymnastics*. At the age of 18 every youth began two years of physical training for war. Some of the physical training was overdone and over-specialized, particularly after the age of 20 and when devoted to competitions in the festival games. Against such specialization, though supported by Pindar, Xenophanes and Euripides protested, a protest supported long afterwards by Galen.'

This protest has obvious cardiac as well as more general implications, and must not be overlooked to-day.

'In the Periclean age secondary education, including gymnastics, was introduced for some boys from 14 to 18, when they entered upon military training. Of the three grades, primary (6–14), secondary (14–18), and tertiary or military (18–20), the first had been authorized since the time of Solon but was not universal, the second was entirely voluntary and for the richer classes, and the third only was both compulsory and provided by the State, the gymnasia and palaistra being built at public expense. This is the "system" of education extolled in the *Republic* of Plato. The necessity of letters is obvious; the music provided harmony and rhythm, the balanced mind; the physical training (consisting of running, jumping, discus and javelin throwing, wrestling, swimming, riding, dancing, &c.),

combined as it was with physiological hygiene and dietary, with baths, massage, rest, and sleep, was the most thorough and continuous of the subjects of the curriculum, gave physical health and strength of body, and was a "test of character". This is what Plato says: "The conduct of a man is a very important test of his character; and those who establish a system of education in music and gymnastics are not actuated by the purpose of applying the one to the improvement of the soul and the other to that of the body. They introduce both mainly for the sake of the soul." '

In this digression is indicated the right use of rest—change of occupation, with its beneficial effects on the functioning of arteries and capillaries, and consequently upon blood pressure.

It is generally held that the limits in normal individuals at rest range for systolic pressure from 110 to 135 millimetres of mercury; for diastolic pressure from 60 to 90 millimetres; and for pulse-pressure from 30 to 50 millimetres, but it must be remembered that individual variations are common and quite compatible with vigorous health. Repeated examinations of such persons under different conditions of physical training will reveal sometimes far greater adaptability than has been suspected previously, unless cognizance has been taken of the physical type from the beginning—a point to which further attention will be given later in this book.

W. C. Alvarez and L. L. Stanley (1930) conclude that the blood-pressure varies only slightly between youth and old age apart from the effects of definite physical diseases. Those who have a high pressure at 40 probably had it at the age of 20, and the importance of noting this in early life will obviate a great deal of unnecessary anxiety in later life. It must be remembered that some human 'engines' are higher powered than are others, and that a distinction must be made between 'lymphatic' and energetic types from the point of view of physical and physiological capabilities. It is most unwise to drag in psychological considerations until these two classes of capabilities have been clearly

defined, but with such knowledge as the starting-point psychological work can be of the greatest benefit in all cases. Worry and chronic fatigue tend to raise the blood-pressure, and may even be advantageous in cases which would otherwise tend to an unhealthy laziness. There are far more cases of ill health due to insufficient development and employment of the body and mind than cases due to over-strain.

Postural changes generally raise the systolic pressure slightly in a majority of normal persons, though not in all, but an excessive change may indicate maladjustment, and this is not always due to disease, but sometimes to under-development of the body mechanism. It is obviously important to secure a correct diagnosis in this respect because the treatment of this condition (with its symptoms of faintness, dizziness, &c.) will differ radically in different cases. There is already ample scientific and laboratory knowledge to equip the medical adviser to do very good work; there is a distressing lack of records of such clinical work, most of those who are doing it being too busy to write down their findings. There is also a sad neglect of this very practical subject by the established medical and educational periodicals of the day; with more encouragement more clinical work would be published, and progress would be more rapid.

E. C. Schneider and D. Truesdell (1922 and 1923) may be cited as affording illustration of both the scientific and practical aspects of this particular question. They found, for example, that men who had a very low systolic pressure when standing were usually those who had a higher pressure than normal in the recumbent position. The group in which the standing posture pressure ranged between 110 and 112 millimetres of mercury showed little or no change when lying down, while those with a higher standing pressure usually showed a fall when adopting the reclining position. The diastolic pressure usually, but not invariably, rises with

the assumption of the standing position. The practical deductions to be drawn from these points have yet to be evaluated.

Miss A. H. Turner (1927, 1929, and 1930) has studied the changes in the arterial blood-pressure in young college women during standing quietly for a quarter of an hour—a difficult feat for some. Failure to adapt to this exaction is shown by feelings of restlessness, or even great fatigue, dizziness, and faintness. She considers that the best reaction comprises: a rise in systolic pressure; a rise in diastolic pressure, without undue lowering of the pulse-pressure; a pulse-pressure of about 25 to 30 millimetres of mercury, and certainly not below 20; and the maintenance of all these conditions without large fluctuations or progressive change. She adds that a pulse-pressure of more than 20 millimetres is seldom associated with dizziness. It must be remembered in this connexion that changes in the blood-pressure during the first minute or two after assumption of the standing position are related in part to the muscular work involved, and must therefore be discounted to some extent.

EXERCISE AND BLOOD-PRESSURE

It will be obvious that the practical importance of the foregoing scientific details is especially manifest in muscular activity, whether as regards the daily work or recreation, and a whole book could be written on the subject. In order to maintain a sufficient supply of blood to the muscles, the filling force must be great enough to supply the capillaries and veins as soon as relaxation of the muscle begins. The velocity of the blood-flow is determined largely by the arterial blood-pressure, which must rise, therefore, to meet the demand by the tissues for extra supplies of oxygen. W. P. Bowen (1904) illustrated these changes during thirty-two minutes of work on the bicycle ergometer and the following half an hour of rest. The systolic pressure rose

rapidly as the work began, and continued to rise for about eight minutes; it then fell gradually as the work continued, but dropped sharply when it stopped. In a case illustrated the pulse-rate had not returned to normal in the twenty minutes after rest began, and the systolic pressure remained subnormal for a time after exercise.

This note is inserted as a warning against too hasty an application in practice of such scientific considerations as have been mentioned, with the drawing of too dogmatic deductions on an inadequate number of observations. It has been the custom of some of us to demand a return of the pulse-rate to normal or subnormal within five minutes or so of the resumption of rest as a standard of healthy adaptation, and as a rough routine procedure this test is useful, but it must be realized that the important factor is the adaptability of the individual to various loads of work of differing lengths of time, and that generalizations must be very guarded, since individuals vary so widely even within the limits of healthy adjustment.

As a rule, when muscular exercise is sufficient to raise the pulse-rate it provokes a rise in the systolic pressure. While in prolonged work the primary rise of the systolic pressure gives place to a subsequent decline it rarely reaches the normal level in fit persons. There is a greater rise in such more exhausting exercises as running and strength exercises (Schneider, Cheley, and Sisco, 1916; O.S. Lowsley, 1911; and J. H. McCurdy, 1901); most of the muscles of the body are in simultaneous action, the blood-flow in them is checked by contraction, and the resistance to the circulation is increased enormously. It will be remembered that R. D. Gillespie (1924) showed that the systolic pressure was also increased by mental work.

Lowsley's findings were as follows. Systolic pressure is higher after rapid and exhausting exercises, the rise depending on individual characteristics and on the amount of energy expended. The pulse-pressure rise is greatest after

this form of exercise. The pressures fall below normal after 10 to 30 minutes; the systolic pressure fall is about the same for all types of exercise, though slightly more marked in exhausting exercises, while the diastolic and pulse-pressure fall is about the same after all types of exercise. The systolic pressure returns to normal after the subnormal phase more slowly after the more exhausting exercises; this slower return to normal is observable in the diastolic pressure after the more rapid and exhausting exercises, and in the case of pulse-pressure after the more exhausting exercises. The subnormal phase may last for several hours after the more exhausting exercises, but the return to normal is swifter in rapid exercises if the physical condition is good. Further reference to this practical point will be made later.

The cause of the sudden fall immediately after the cessation of muscular effort may be due to the sudden stopping of the cardiac forcible action (Bainbridge, 1931) or the reduction in its output (Lowsley, 1911). The anticipatory increase of pressure before exercise is brought about by an increased frequency of the heart-beat and the splanchnic vasoconstriction. Emotional factors may be concerned in this also, and conditioned reflexes are operative. At first there is vasoconstriction of the skin, but later dilatation ensues so as to aid in the emission of heat and water. The chemical products of muscular activity cause the opening of the capillaries in both the skin and muscles, partly by direct action and partly by stimulation of the vasomotor centres.

THE CAPILLARY CIRCULATION

The blood-flow through the capillaries is the essential factor in determining the efficiency of muscular activity, but there is clear evidence that their size is not the only important point. Their tone is dependent to some extent on their essential contractile powers, and this factor varies in different persons, presenting another individual consideration in

determining how much exercise a man can do and also the nature of it which is most suitable to him. It must be realized at once, therefore, that there are physiological as well as psychological reasons for the variability in interest in physical exercise as a whole and in various forms of it shown by human beings—a fact which is being increasingly recognized in devising schemes of physical development for youth and for physical recreation in adult life. The advocates of special schemes of exercise are as yet not fully awake in this respect, and better progress will be made in the country as a whole when practical recognition is given to this matter, and attempts are made to define in advance which forms of exercise are likely to be more acceptable to different individuals as well as to different classes of the community. The greatly increased interest taken rightly in psychological questions nowadays must not be allowed to distract attention from these physical and physiological differences between persons and classes.

The contractility of the capillaries may be regulated by their nerve-supply modified by a pituitary hormone (A. Krogh, 1922), adrenalin (Dale, Laidlaw, and others), or the acid-base balance of the blood (A. Hemingway and R. J. S. McDowall, 1926). The importance of histamine in this connexion has been more recently stressed. E. M. Landis (1928 and 1930) believes that the permeability of the capillary wall is a matter of osmosis and diffusion, and that the lack of oxygen is an important factor, as well as the accumulation in the blood of the products of muscular activity (metabolites).

The work of Lewis on the 'H'-substance is also significant, especially as regards the blood-vessels of the skin. Means attaches importance to a consideration of carbon dioxide transport and the regulation of the blood neutrality. He states: 'Pulmonary ventilation and blood-flow then are both pitched at such rates as will, while taking care of the metabolic demands for gas transport, at the same time

preserve blood reaction and, by providing a wide margin of safety with respect to oxygen tension, obviate any danger of asphyxia even though through muscular work or other agencies the metabolism may undergo rapid and gross alteration.' He believes that the carbon dioxide tension or the blood reaction regulates the blood-flow as well as the pulmonary ventilation.

This chapter may well be concluded by pointing out the importance of muscular exercise in promoting health. It has been shown that both the respiratory and circulatory functions are largely determined by muscular contractions. Evidence has been adduced indicating that there is reason to believe that different types of persons will have their physical and physiological requirements met by different forms of exercise, and that relative failure will attend an attempt to press any one form upon the community. From physiological considerations alone it is obvious that a physical health campaign must be a multiform effort, and that those who are charged with the task of directing its progress will be in very grave danger of falling short of appreciable success unless they take full cognizance of what is already known about the physiology of the body as well as providing full facilities for securing the benefits of the new researches which are being made.

XIV

BENEFITS OF EXERCISE

At this point some general conclusions from the foregoing findings can now be drawn with a view to indicating the further evidence to be called. So far the chief emphasis has been laid on physiological considerations, though reference has been made to anatomical and psychological questions which with other practical topics of physical education will be dealt with in the following chapters.

It must first be reiterated that it is difficult to find any men who have been injured, other than accidentally, by muscular exercise or indulgence in sports, but very easy to discover many who have for lack of physical training failed to develop or mature properly, or who have by faulty habits and methods of living laid themselves open to disease. The medical advisers and physical educationalists are charged with the task of securing full development of the body—which brings with it development of the mind and spirit, and this must not be overlooked in the rush of 'keep fit' activities which are becoming popular to an almost dangerous extent. The danger lies in the fact that under-development must be treated first; this includes under-development of the latent functions of the lungs, heart, &c. Many to-day do not realize that they have yet to 'get fit', and that this involves a very different outlook on physical education from that of those who are only concerned to 'keep fit'. Both medical and lay teachers must be able to recognize when the first stage has yet to be completed.

Growth is not wholly completed at the age of 21, even from the physical standpoint, and still less from the physiological one. Systematic physical exercise increases the

height, weight, and vital capacity of growing boys though not always the chest expansion; optimum standards for individual persons must be sought in practice in preference to standards for groups of persons, and the medical adviser or gymnastic leader must not allow himself to be too prone to draw conclusions from statistical tables, even of his own compiling, since many of the factors of health and efficiency have yet to be scientifically standardized. We are still groping in this respect, and much harm has been done by the loose talk of a C 3 nation in the past. For instance, recruiting statistics are very much modified by the inclusion in them of rejects for reasons which do not in the least interfere with healthy and happy civilian life. The very basis of such statistics was undermined in the war by the discovery that many of the then criteria were unsound, although they served at first well enough as a rough and ready method of selecting the apparently best men for a specific purpose while the supply of men was more than ample. The testing nowadays relates more to function than to physique, and many who are physically inferior in a few respects have been shown to be greatly superior in the stress of living than their physical betters.

It is well enough realized that better feeding increases the weight of some advantageously, of others disadvantageously; this is never the case when better nutrition is the objective—a distinction with a most important difference. A man is better able to assimilate and make use of his food when subjected to appropriate exercise, as recent work in the Army and elsewhere has made clear. The entire skeleton and individual bones are capable of modification by the action of the muscles, even after youth, and the curvatures of the spine with the shape of the legs and arms are governed to a great extent by personal habits. Hard work, for instance, increases the density of bones, and the cancellous plates at their ends become rearranged to withstand persistent or repeated strains; it may also lead to digestive and

muscular improvements which will render life happier and more effective.

A man in poor physical condition is easily exhausted by mental or physical exertion. He is irritable and morbid, suffers from petty ailments, and has a poor morale. Many of the great physical achievements of the past were wrought by underfed persons, their labours inducing in them a better power of utilizing what food they had, while their heart and lungs as well as their muscles functioned more powerfully as well as more economically. Their 'training' removed their previously sallow complexions, dull eyes, constipation, headaches, nervousness, and insomnia. A man in good physical condition should show signs of mental as well as of physical vigour, such as alertness, cheerfulness, high morale, bright eyes, elastic step, healthy complexion, and a capacity for arduous toil—signs not always associated with good feeding! Such improvement under training indicates physiological changes in the body, including a better functioning muscular system and a greater range of adjustability of the circulatory, respiratory, and nervous systems.

Regular muscular exercise thickens the sarcolemma and increases the amount and strength of the connective tissue. The muscle grows larger, not owing to any increase in the number of its fibres but rather to its improved circulation and to the fact that previously small and little-used fibres are made to work and grow bigger in consequence. The gain in power is out of all proportion to the gain in size, the number of contractions possible being much multiplied and their quality being improved, this improvement being associated with the chemical changes by which the muscle fuel is rendered more easily and quickly available. This fuel is stored in greater amount, and the oxygen supply is enhanced, permitting better building up of the broken-down compounds—as previously explained. There is a definite increase in the phosphocreatine content which lasts after

the termination of active training, and also of glycogen and haemoglobin, the used muscles becoming redder. There is a quicker transmission of nerve impulses through the muscle end-plates. The muscle operates in its entirety, and the team work of the fibres is more satisfactory. There is better co-ordination of the action of different muscles, if the training has been sufficiently varied in its planning, enhancing skill and ease of action. Many new capillaries are in action, and they are more practised in responding to calls made on them.

The superiority of the athlete lies in his ability to retain during exercise an internal bodily environment which differs only within narrow limits from that at rest. This mainly results from his readier ability to supply the oxygen required for the increased metabolism caused by muscular exercise, but this change can equally well be utilized for mental work or resistance to emotional strain. If graded exercise is taken day by day, the load of work can be gradually increased until what was an exhausting load at first can be easily and comfortably carried. This is the vital part of the process of 'getting fit'; its maintenance comes under the head of 'keeping fit'. The muscular capacity of a man is measured by the extent to which he can call upon his body for increased effort, and can balance the oxygen breathed in to that required by his muscles. E. M. Kagan and P. M. Kaplan (1930) showed that physically untrained mental workers spent 23 per cent. more energy in a certain measured amount of physical work, using up a correspondingly greater quantity of oxygen, than did trained manual porters. In this connexion it must be remembered that the recruit learning to march uses at first more muscles than are necessary, and works less economically those which are actually necessary. In one of their experiments it was shown that training reduced the amount of carbon dioxide in carrying a weight of 2 pounds and 3 ounces for just over 3 yards from 85½ ounces to 74; this implies a reduction of 13·5 per

cent. of the oxidative processes. Such a gain in efficiency begins to be acquired quite early in training.

During exertion the trained man reconverts the lactic acid to glycogen as fast as it is formed in the muscles; in the untrained man lactic acid passes into the blood even in mild exertion, and soon induces fatigue. The lactic acid is taken up by the sodium bicarbonate in the blood, but this buffer action is soon exhausted in the untrained person, limiting his endurance and power of performance irrespective of his will power or any emotional stimulation. Physical training actually increases the alkaline reserve of the body, namely the ability to neutralize the acids consequent on fatigue, an obviously necessary phenomenon, since the basal metabolic rate, which is the measure of the active chemical processes going on in the body, is increased 10 to 15 per cent. by training (H. Herxheimer, E. Wissing, and E. Wolff, 1926). This increase in the alkaline reserve has been estimated at 7 per cent.; indicating that at least half of the extra strain which would otherwise have been thrown on the body by the intense training has been obviated by more economic functioning of the whole muscular and cardio-respiratory systems. Sickness decreases the alkaline reserve, hence the muscular weakness after fevers, &c. It is possible that some of the alkaline remedies of proved therapeutic value owe some of their popularity to this fact. In well-trained athletes exercise is not followed by increased acidity of the urine, as is the case in the untrained man, the internal environment of the body remaining steady, thanks to the better use of oxygen.

In most persons training tends to increase the chest expansion but, as previously indicated, this cannot be taken as a reliable sign of efficiency. The increase in depth is more important. In the sedentary person much of the lung area is almost unaffected by the shallow breathing, while training brings the whole of it into use. E. Hörnicke (1924) found that in untrained persons the diaphragm moved very

little in breathing, the frequency being 18 to 20 a minute; those trained in sports had a deep diaphragmatic breathing with the much slower and more economical rate of 6 to 8 breaths a minute. Lung capacity cannot be determined by measurements of the chest because these take no account of diaphragmatic action. It cannot be emphasized too forcibly that some athletes with good-looking chests and excellent vital capacities may quickly get out of breath during exercise because of faulty use of their respiratory mechanisms. Thus again is indicated the importance of testing function rather than physique. In the case in which a poor chest is associated with good breathing powers the diaphragm will be found as a rule to be functioning exceptionally well.

The right time for concentrating on development of the chest is in youth, when exercise will enlarge it. The forms of exercise which are best suited to this purpose are those involving running at speed and long-distance running which inculcates endurance. To submit boys and lads to exercises which do not directly aid in chest development—a very different thing from development of the accessory muscles of respiration—is to neglect the golden opportunity, and this is one reason why outdoor competitive activities are so naturally popular with youths of both sexes. They feel the instinctive call to development, and the necessity of providing facilities for this development in the form of playing-fields is especially urgent between the ages of 14 and 18 and in the vicinity of towns. Failing these, a great deal can be done by running games in gymnasia.

In the *Physiology of Exercise* by F. A. Schmidt and C. B. Sputh (1931) there is a well-justified attack on the reliance at this age on marching exercises, roundel dances, and rhythmic drills. The authors deliberately except what are termed folk dances, but describe the others as 'a senseless aggregation of intricate motions . . . composed by people who have no musical feeling and who have no conception

of beauty or appropriateness . . . such concoctions have no gymnastic value'. Whatever may be said in rebutting this charge, it must be admitted that such practices do not tend to development of the chest in children and adolescents.

A trained man breathes less air, but uses a greater portion of the oxygen in it; he ventilates his lungs more economically during rest and exercise, and hence is less evilly affected by sedentary occupations in later life, even though his 'keep-fit' work has been much reduced. This economy of effort is particularly valuable during exercise; it is largely effected by a great increase in the capillary diffusion area of the lungs, thus enabling a greater quantity of blood to be aerated in a given time. After exercise by untrained persons there is sometimes seen a tendency to the Cheyne-Stokes type of breathing, the individual breaths waning and then increasing in a rhythmic fashion (Schneider). This is not found in well-trained men.

Reference has been made to the increase during training of the volume of blood expelled from the heart each minute, and the consequent useful and comfortable slowing of the pulse-rate. Investigations confirming this very beneficial change have been recorded by C. Bramwell and R. Ellis (1929) on Olympic athletes, F. S. Colton (1932) on Olympic swimmers and women, and P. M. Dawson (1919) who dealt with the effect of physical training and practice on the pulse-rate and commented on the complications introduced by certain acute infections and the distress resulting from exercise. In these last two connexions he noted how much less was the depressing influence in the case of the physically trained man—another argument for more extended physical education. Regular training appears to intensify markedly the tone of the vagus centre in the brain which slows the pulse-rate; the rate in a resting trained man is from 6 to 8 beats slower than when he is out of condition.

The trained heart pumps out more blood per minute with fewer strokes; the slower pulse allows more resting time for

the cardiac muscle-fibres. The athlete empties his heart more completely at every stroke, and its beating rate returns to the normal more quickly after exercise, in marked contrast with what occurs in the physically unfit. For example, it has been shown that in a series of tests which involved the brisk climbing of twenty-seven steps the pulse-rate returned to the normal in trained men in one minute subsequently while untrained men required as long as five minutes. The determination of the arterial blood-pressure at rest is of little value in most cases in estimating efficiency (C. Bramwell and R. Ellis, 1929), but P. Stocks and M. N. Karn (1924), in a study of blood-pressure in early life, found that regular physical exercise tended to keep down the diastolic pressure by reducing the peripheral circulatory resistance and improving the tuning up of the body. This fact constitutes a most important argument in favour of promoting physical training with a view to lessening one of the causes of disablement and death in later life.

There is little doubt now that such training, if carefully graduated and adjusted to the individual needs, improves the nutritive condition and develops the muscular condition of the heart at the same time that it strengthens the skeletal muscles and enables them to function more healthfully (Bainbridge's *Physiology of Muscular Exercise*, revised by A. V. Bock and D. B. Dill, 1931). It may possibly increase the number of red blood corpuscles and the amount of haemoglobin, but this has not yet been proved, though the evidence of R. Isaacs and B. Gordon (1924) suggested that regular physical exercise helped to maintain an efficient corpuscle-forming mechanism. R. Ackermann and F. Lebrecht (1928) found that a course of training in rowing increased the number of red blood corpuscles, and indicated a possibility that over-training might have the contrary effect.

Observations in Schneider's laboratories seemed to show that there was a pronounced individual factor in the response

of men to training. He and A. O. Foster (1931) reported that regular daily physical exercise might increase the amount of active protoplasm in the body, and so intensify the work which the body tissues had to do, with a consequent greater taxing of the heart and lungs. This is probably compensated by a greater skill in securing the full advantages of rest periods, both by individual cells and by the body as a whole. 'The athlete somehow learns how to relax very well', but it is more than doubtful whether in ordinary physical training schemes for ordinary working people the importance of ensuring that this boon is conferred is adequately appreciated. To induce tissue hypertrophy without simultaneously arranging for the development of this compensatory mechanism is to invite disappointment if not disaster, and the mere provision of rest periods does not necessarily imply that they will be used properly by the body. Short spurts of 'getting fit' will not suffice if there are no provisions for 'keeping fit'.

In Bainbridge's text-book Bock and Dill refer to the work of N. J. T. M. Needham (1923), who suggested that the haemoglobin pigment in muscle might be no more than an end-product of muscular activity, but it is more probable that this substance has a catalytic action or may aid in oxygen transport. It is certainly found in greater amount in muscles which arc submitted more frequently to activity or to stress. Further research in this quarter may have a practical bearing on training schemes. But it can now be deduced that exercise is not solely concerned with the problems of breathing or of the functional capacity of the heart, although it is still necessary to emphasize the importance of these. Too much emphasis has been laid in the past on the question of the possibility of heart strain, the heart being considered as the limiting factor in exercise, and medical practitioners have in many cases been far too anxious to reduce the amount of exercise as a routine in cases in which some nebulous symptoms have appeared in

the course of training. In them it is of great importance to make a much more exact diagnosis of the existing conditions than has been hitherto customary, for many of life's so-called invalids ('strained my heart when young') are not victims of excessive exercise, nor does disordered action of the heart necessarily imply organic mischief. Assuming that electrocardiographic records reveal no trouble, the possibility must be admitted for consideration that under-development and under-use are calling for treatment, and that psychological factors have come into the story to complicate the clinical picture further. The medical adviser in the gymnasium, &c., will have many such cases to consider, and must be well equipped with a diagnostic armamentarium lest he blunder and doom a person to an evil as well as an unnecessary life of physical lassitude.

To this it may be added that there is no evidence at present that the length of life of athletes is any less than that of those who indulge in less strenuous physical exercise, and that old bogy may be ignored. L. I. Dublin (1929) recorded a study of the longevity of 5,000 college athletes in the United States who finished their university education in 1905 and earlier, and his statistics indicate that in this class of the community the expectation of life is greater than the average, in spite of their increased liability to accidents. He is rather doubtful about the incidence of heart disease in later life, especially when the athletic pursuits involved excessive cardiac strain, but there are insufficient data as regards, for example, the incidence of non-infective arteriosclerosis in later life, to express a very definite opinion, and the pessimism of some rests at present on no scientific basis. Further research is urgently needed.

In the *Physiology of Exercise* by F. A. Schmidt and C. B. Sputh (1931) further evidence is cited, and it is pointed out that a moderately enlarged heart is not at all equivalent to a diseased heart. Pure dilatation is admittedly a sign of failure of adjustment. Preliminary preparation before in-

tense training periods can undoubtedly ward off immediate and remote ill effects, especially if followed by duly graded and progressive work. The importance of choosing developmental exercises and sports suitable to the age of the subject is stressed. Reference is made to the researches in this connexion of Zuntz and Schumburg (1901), H. H. Meyer and R. Kaufmann of Vienna, Deutsch and Kauf (1927), and Beneke of Hamburg. Attention should also be called to the findings of A. Abrahams (1928) and to those of H. M. Vernon (1928 and 1929) with especial reference in the case of the last named to the effects of heavy industrial work. A survey of the rapidly accumulating literature will convince the previously unbiased reader that the time has not yet come for the drawing of final conclusions.

XV

PSYCHOLOGICAL FACTORS IN PHYSICAL EDUCATION

THIS would appear to be a suitable point to refer rather summarily to the relation of psychological phenomena to physical training, because the benefits indicated in the last chapter have psychological repercussions. Some of these are conscious, but others are buried in what has been termed the 'subconscious' or 'unconscious' (no exact differentiation is necessary here) and are only observable by their consequences. Again it must be remembered that psychological considerations are often potent in determining the success or failure of schemes of physical training, and some general knowledge about the basic facts is therefore essential if physical education is to proceed healthily and effectively.

Many physical proficiencies and deficiencies have a psychological origin. Thus an innate desire to excel, especially when coupled with failures in other walks in life, may lead to the emergence of a great athlete or famous sportsman. Such an innate drive (whatever its origination) may be detected by the posture or gait, and be distinguishable thus from an urge to humiliate others or to revenge oneself for real or fancied slights. Many a one who has felt himself to be a round peg in a square hole in life, finds the round hole for himself in an athletic occupation of some kind, and subsequently proves to be a great benefactor of his acquaintances. This is by no means to suggest that the 'fool of the family' should go into physical education; that idea has long since been rejected. 'Flannelled fools' or 'muddied oafs' are now in danger sometimes of being rewarded too lavishly and of forgetting that there are other spheres of life which they must explore if ephemeral suc-

cess is not to leave them disheartened at the last. Mind must co-operate with body if the best results are to accrue to the individual as well as to the race.

On the other hand, a lad who is feeling weighed down by a load of home discords or troubles at work tends to assume unconsciously almost the attitude of one who is carrying a material load on his shoulders; his head is bent, his shoulders are rounded, and his actions are slow and laboured. If relief does not come, the posture becomes habitual; the spinal muscles lengthen and the pectorals shorten. Attempts to restore the normal position of his body and limbs by drill or gymnastics, even though gladly accepted as a temporary escape from his affliction, will fail to win lasting success because his attitude to life determines his physical bearing. It has even been said that all faulty habits of muscles are due primarily to faulty habits of mind; correction of these last is not always difficult, provided that the medical adviser or gymnastic instructor is observant, able to discriminate and diagnose accurately, and has been trained in practical elementary psychology.

It should be remembered also that muscle weakness and deformity is more commonly found in the extensor rather than in the flexor muscles; some have traced this phenomenon back to the acute flexion of the child in the womb, and have found evidence in many cases of the existence of an attempted 'retreat from life' back to the sheltered irresponsible state before birth. Functional faults of muscles may reflect faulty reactions of the mind to circumstances, but they may also be due to under-development of muscular structure or of activities which brings about a wrong attitude of mind. Many a so-called inferiority feeling, or complex of feelings, is traceable to some slight organic inferiority which has almost unconsciously 'preyed upon the mind'. The medical adviser is often called upon to explain the unimportance of such structural irregularities, and should be ready to help the victim to change his out-

look. In such cases it will be found that Nature has nearly always provided some very real compensation, although it may have been overlooked, and the medical adviser should develop a keen eye for 'buried talents'. He will then be able to restore both body and mind simultaneously to a healthy state, and unveil a hitherto hidden capacity for physical as well as mental prowess.

From the point of view of practical physical education three psychological conceptions require mention: the conscious and subconscious; the variable nature of human reaction to environment; and growth changes. In these pages only brief attention can be paid to them, but they are well worthy of careful study in the playing-field and gymnasium as well as in the library.

THE SUBCONSCIOUS MENTALITY

Three illustrations will indicate the way in which this works, and will serve as an introduction to psychological text-books which deal with motives for action. Allegories must not be pushed too far, but they can be very useful in conveying general ideas.

On an iceberg floating southwards from the north pole there play winds from various directions in turn on the one-seventh part above the water level. Currents operate unseen below the surface on the submerged six-sevenths. Assume that the part above water can think consciously; how puzzled it must be at times when it finds itself moving against the wind which it feels is trying to drive it in another direction. Assume also that the upper part of the iceberg has some will power; it finds its conscious efforts flouted in a most baffling way, the current action on the submerged six-sevenths being so powerful. The upper part 'thinks' what it would like to do; it 'wills' an action; and then the submerged subconscious part makes it 'feel' that it cannot do what it has planned.

Watch a lad in the gymnasium about to vault. He runs to the box and jumps but fails to clear it. He thought of what he was going to do, he really wanted to vault successfully this time, but fear, often an unconscious fear, limited his muscular action. The medical adviser, watching with insight as well as sharp vision, can distinguish between a failure born of lack of skill and another due to unconscious fear. He gives the right treatment, often a simple matter, and not only is the vaulting accomplished properly, the muscles no longer being afflicted by divergent emotions, but a great forward step has been taken towards reducing fear in life generally to its proper place. The treatment is necessarily different when the fear is conscious.

Again the subconscious part of the personality has been likened to a pool; on the surface some leaves and other objects float for a while before sinking to the bottom. Down there they may decompose, sending up bubbles which disturb the surface calm. Or powdered salts may dissolve after falling from the surface to the bottom, and alter the nature of the water.

Quiet hints delivered apparently carelessly about style in batting or instructions about the right way to use muscles in some gymnastic performance can be soon forgotten and yet leave lifelong traces in the subsequent actions of the pupil, actions which have become habitual. Here many mistakes have been made in the past, and are being made. Leaving aside cases of 'conditioned reflexes' which have been mentioned earlier, and it being remembered that such deliberate conditioning is a very difficult matter very often, it cannot be too strongly emphasized that repeated actions do not always lead to habitual actions. It is 'feeling' that matters, and physical training makes much faster strides in any person when he 'gets the right feeling', while on the other hand many are barred from progressing because they do not realize the wrong feelings which are attached to faulty actions; they cannot therefore correct their faults,

even with the best intentions. How to inculcate the right feeling in different respects and with regard to different exercises is one of the most important attainments which a physical educator has to possess. Eventually the right feeling, having had its period of conscious existence, sinks into the depths and becomes the 'subconscious right feeling' in respect of physical activities.

The third illustration of the working of the subconscious self is that of a house; its basement is full of wild animals of different kinds, some of which are dangerous to the human occupants while others can be very useful if suitably trained and controlled. Ignoring the existence of the basement and its denizens (the subconscious) leads to troublous times, when some of the animals break loose, and to waste of potentialities always. To go down into it with a view to examine and chain or train the animals is a risky proceeding, even to the experienced, whether he be the householder (person concerned) or a kindly friend (psychotherapeutist). There is here no dreadful dilemma in practice, however, for the compromise way of treating the situation lies open, that of self-reverence, self-knowledge, and self-control. Evidences of this 'basement' part of the personality, without which by the way the whole house would crumble into shapeless useless ruin, are afforded by dream memories which are often symbolic, unconsidered acts and words, and some physical characteristics noticeable by the observant. The barrier to the unfettered emergence has been personified for reasons of convenience of consideration as the 'censor', a state of inhibition built up by training, experience, conventions, racial trends, &c. The 'animals' include such urges (I avoid the word instincts for technical reasons) as fear, 'lust' to live fully and to develop to the limit of innate capacity, self-preservation and self-reproduction, the winning of security, and the avoidance of injuries to the personality including the physical body, &c. Even in our present limited field of physical education both

the subconscious and the conscious parts of the personality have to be considered.

The discipline (discipleship) of physical drill may engender a fuller and more fruitful life of the mind and soul. Chaotic gymnastic programmes will only result in boredom and disappointment for those who consciously or not are seeking guidance. Exercises of speed and endurance confer powers of mind as well as of body if accepted by the pupil, and result in a healthy, because controlled, self-expression and self-gratification. Even repetitive work may not be boring for those who find the vicissitudes of the life of emotion and activity too exacting, and may have a healing value. In short there are few phases of the many forms of physical training which can be branded as bad or good for all from the point of view of getting and keeping fit. There is an art as well as a science in adjusting the training to the various needs of various types of personality and capability, and this results in the profession of physical education being one of the most valuable and enjoyable of all human activities.

REACTION TO ENVIRONMENT

Some persons live primarily in themselves and their sensations (introverts) while others live primarily in the projection of themselves into their environment (extraverts). Most of us are mixed, with one or other of these trends predominating at different times; in some of us the prevailing trend is less variable from hour to hour and day to day. Two classes of physical activities can thus be distinguished, and both must be blended in any scheme of physical training if it is to be generally popular and to do permanent good. Life calls for three adjustments to be made: to the general environment of the life; to the mate; and to God, and the man or woman is imperfect in so far as this triple adjustment has not been made—which is not to say that all must marry or all must be leaders, &c. There

are twin aspects in such adjustment: attack and defence; advance and retreat; boldness and cautiousness; acceptance and refusal; criticism and acquiescence, &c. All these are necessary at different times because man is essentially a gregarious or social being. But it must not be forgotten that a man must get on good terms with himself (adjustment again) before he can get honestly on to good terms with others; hypocrisy leads eventually, early or late, to disillusionment and disappointment.

For some persons physical training provides a new environment to which at first they find it difficult to adjust well. When they have overcome this difficulty, which is not of the same causation for all, they find that they have learnt something more about the way to adjust themselves to the demands and opportunities of life. Adjustment to the external environment of the sports field or gymnasium brings with it for some a greater power of adjusting themselves wisely and profitably to the internal environment of their own personalities, continually changing as both these two environments are. The demands made by climbing a rope are different from those of free-standing exercises, or of football or swimming, or of agility work, or of boxing and fencing, &c. There is an immense possible variety of programme in physical education, and psychological as well as physiological requirements indicate that no one scheme, however cunningly devised, can possibly meet the needs of all types of physique and temperament. Consequently, a national scheme must be very broad in its scope, and allow all types to find the facilities for their development and full disciplined self-expression.

GROWTH CHANGES

Many psychological 'ages of man' have been differentiated, and all such classification schemes have advantages and disadvantages. The following one is only submitted to illustrate the main principle, though it leads to practical

conclusions as regards physical education. The young infant (self-pleasure) stage leads on to: the 3rd year or so of life (conflict, owing to the gradual realization of an external environment to which adjustment must be made—represented by parental dictates, &c.); to the years 3 to 8 (young animal, calling for games satisfying individual urges); to the years 8 to 14 (the young human savage, more gregarious and requiring team games as well as competitions); to the years 12 to 15 (puberty, calling for modifications of physical activities in accordance with the intensifying sex differentiation and urges); to the years 15 to 18 (adolescence, calling for activities which will subserve the joint introspection and circumspection which are associated with a greater intensity of living including personal rivalries and alliances); to the years 18 to 21 (young adult state, with its clearer objectives, precipitancy, sensitiveness, idealism, and desire for self-protective concealment); to the years 21 to 40 (adult state, with its realization of greater though often uncompleted maturity and of things to be done rather than contemplated; and to the time 40 years onwards (fool or philosopher in physical as well as other activities).

This very rough classification is suggested only from the practical point of view of physical education, though founded on psychological lines. The stages overlap; some persons in any age group are ahead of others, and some behind their fellows, but greater elaboration would be impossible here, though by no means difficult in practice. The indications given in brackets are for forms of physical education, and the reader should be able to draw general conclusions easily enough as to what forms will be roughly the most suitable—from the psychological point of view—at different ages. A return will be made to this practical point later, anatomical and physiological considerations being collated with the psychological.

So the growing human being clothes himself with experience and with some understanding of his reactions to

experiences. Some linger unduly in various stages, and some 'regress' to earlier stages under strain. For instance, fits of temper or inordinate desire for consolation are common regressions to childhood when occurring in persons of full adult age. Other examples of retarded psychological development or of unhealthy regression include an undue interest in gambling activities (life not exciting enough; desire for better results without willingness to expend the necessary energy; titillation of feelings); drunkenness (too easy and futile an escape from disturbances of the internal or external environment to which attempts at adjustment have previously been ineffective or on the wrong lines, and similarly a retreat from boredom of the mind due to insufficient preoccupation with the activities which might be found in life); illogical, but nevertheless very dominating, feelings of insecurity or fears, which the 'censor' mechanism may often disguise by 'transference' (palpitations of the heart often indicate emotional rather than physical cardiac derangement!); the too easy acceptance of or unpractical resentment against an inferiority position; an inordinate desire to show oneself off (nudism, exhibitionism, &c.), but the word inordinate is of immense significance here, for much of what is condemned by some is perfectly natural and desirable; masturbation (a flight to physical gratification because enough pleasure is not being extracted from the act of living), a practice of no physical importance or harmfulness but signifying that the personality is not being fully expressed however active the life may be; and the various other instances of self-gratification, &c.

These are a few of the many indications of a failure to grow up owing to some retarding influence (such as an over-anxious or over-indulgent mother, home discords in early life, emotional disasters in youth, continued repression by others, &c.) or a too ready inclination to regress to an earlier outlook on life, which was correct at first but has been outdated with the passing of the years. It must be added that

such a victim may over-compensate. The bully is often a coward at heart, and his cure turns on the removal of his subconscious fears or feelings of inferiority—which may in some cases be brought about by athletic training of the appropriate kind. The very pious man may be so (and recognizably so by those who have psychological discrimination) because he is the possessor of a very morbid conscience, sometimes the fault of his wrong outlook on life and of no sin of his own otherwise. It is a fairly common finding that the one who is always inveighing against dishonesty in others is 'subconsciously' a thief. So the popular idea about inferiority 'complexes' is often laughably wrong. The possessor of such a complex may well be one who avoids the arena for fear of shocking his innate superiority feeling by a defeat!

In growing up psychologically, we carry within ourselves the beings we were. This is indicated graphically in Figs. 6 and 7, taken from *The Quest of the Boy* (Griffin).

Fig. 7, for example, is an imaginary chart filled in for a lad aged 18. The heavy line indicates from which age viewpoint he faces up to certain daily occurrences generally and 'instinctively'.

With a little practice it should be easy to record on a scientific basis the psychological responses to various forms of physical education, to detect the points to which attention should be developed, and to record the progress from year to year. This is not the place to enumerate the emotional and mental characteristics of the various 'ages', but when these have been fully differentiated by the medical adviser and physical trainer their application to physical education of any kind is simple. In *Rover Scouting* (revised edition, 1933) special reference was made by me to the practical work of training adolescent Scouts to become fit in mind and body and to select appropriate recreations. In *Always a Scout* (1932) the same lines were amplified and extended to adult life. The first of the series, namely the

Quest of the Boy, dealt with the physiological and psychological development of boys and youths, with particular reference to the objectives and work of Scout Troops, Boys' Brigade Companies, and Boys' Clubs.

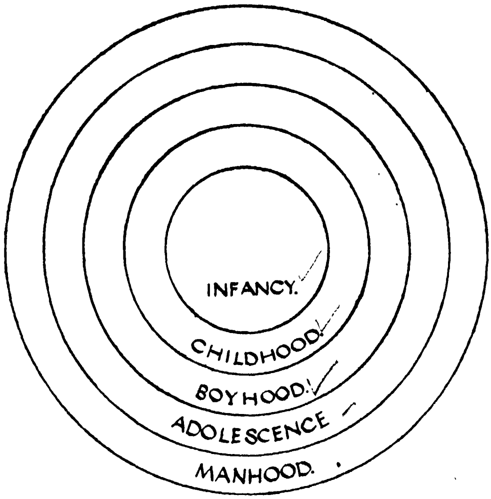

FIG. 6. DIAGRAM OF THE 'MULTI-AGED' ADULT. It is possible to use such a design to record the reactions of a man or women to such various 'environments' as home life, society, disappointments, dancing, climbing a rope, boxing, competitive track running, camping, hiking, exercises of the limbs and body from the standing position, &c., the selected ones being indicated by lettering outside the circles.

In these books I explained more in detail how many youthful and adult faults in development come about; the same applies *mutatis mutandis* to the female sex. With the realization that these developmental errors can be corrected very effectively in many cases by the physical educator who is also a psychologist (although sometimes, especially in older persons, medical considerations come in and render it essential that a medical practitioner who has been trained in psychology and physical education must do the work if greater trouble is not to result) a new era of physical

education is dawning. The old ideals of 'beauty, goodness, and truth' have new practical, physical, and psychological connotations to-day, but they must not be separated from each other for too long even in such a book as this one which is mostly concerned with the 'truth' in physical education (its scientific basis). There must not be too much insistence

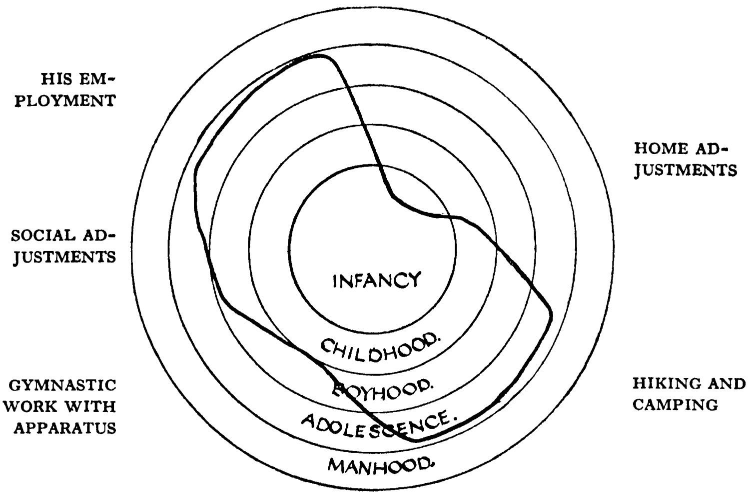

FIG. 7. DIAGRAM OF AN ADOLESCENT'S APPROACH TO DAILY LIFE. His reaction to his employment is normal for his age, but as regards his home he is still in the infantile stage of demanding pleasure and having things done for him as when a baby. His social adjustments are fair, but at gymnastic work he is almost childish, although he enjoys and is good at the adventurous exploring life of hiking and camping.

on the beauty of movements in this training scheme or that, until the essential goodness of the scheme from the physical development point of view has been established as well as the sound scientific basis on which it is founded. Finally, the test of goodness and truth is that they create beauty, and faults can be rightly suspected in many a vaunted scheme because by no standards of beauty can it be approved, and therefore its goodness and truth are probably demonstrably defective.

These general psychological considerations have a very practical application to physical education, and further details must now be given. Mind and spirit deserve as much consideration as body, if the whole human being is to profit by physical education, and the obvious corollary is that mind and body deserve equal consideration when education of the spirit is concerned.

XVI

PSYCHOLOGICAL PRACTICES IN PHYSICAL EDUCATION

As an indication of the great variety of incentives which can be used to popularize physical education in a community containing so many different types of psychological outlook may be mentioned the four groups distinguished by F. A. Schmidt and C. B. Sputh (1931), namely general exercises of strength which demand a maximum exertion of large muscle groups (wrestling, pushing up heavy dumb-bells, and lifting heavy weights); local exercises of strength; exercises of skill (the first of these last two strengthening the smaller muscle groups while the second aim at improving the co-ordination between brain and nerves); and rhythmic repetitions of the same movement, as in running and certain free-standing gymnastic movements of the limbs and body. J. Lindhard (1934) offers a more detailed list including order exercises; exercises in deportment; marching exercises; corrective exercises; balance exercises; running, jumping, and vaulting; agility exercises; games; and athletics. Lindhard quotes C. Lange (1885 and 1899) to the effect that physical exercises are a means of enjoyment, and he stresses this with other psychological points throughout his text-book *The Theory of Gymnastics*. He points out that pleasure is the result of suitably variegated muscular activity, of reaching a desired objective, of winning the plaudits of onlookers by some feat, of experiencing a greater feeling of health and strength or realizing a greater beauty of form, of working together as a team, and of awakening to the possibility of greater achievements in the future.

Professor Pear (1928) enumerated the following incentives for acquiring skill in play. (1) Muscular sensuousness

and epicurean enjoyment. (2) Delight in experiencing power over oneself, over other people, over animals, and over inanimate things. (3) 'Frankly social considerations: desire for fun, for friendship, for approbation, for self assertion and self display, for association with famous athletes, and the varied results of such companionship. In connexion with the motive of seeking fun, the laughter, entirely unconnected with humour, which proclaims successful achievement, both in the baby and in the grown man is immensely interesting.' (4) The impulse towards 'sublimation'—in the sense of the diversion of any primitive impulse from its natural goal which is disapproved. (5) Plunge into play-activity may be a repression of insistent desires, fears, or worries. (6) Deliberate distraction of the mind—side-tracking a subject, not repressing it. (7) Retreat from reality of harrassing responsibility—getting another but less unpleasant reality (for there are penalties, punishments, and dangers in many games). Retreat from boredom. (8) Courting of danger.

Some illustrations of the practical application of the foregoing remarks will bring out the fact that all kinds of human being and all varieties of temperament can receive satisfaction and be helped and developed by the appropriate physical training. It is, therefore, quite unnecessary and even a little ridiculous to suggest compulsory physical education. It is only necessary to provide the right kind for the individual person; he will welcome it when once he has experienced its pleasure-giving properties. The difficulty is to determine in advance, otherwise than by the time-wasting means of trial and error, what forms will appeal particularly to different types, and this problem of 'typing' humanity is no easy one. Possibilities of recognizing different physical types from the point of view of 'vocational physical training' will be dealt with later in this book; in this chapter reference will only be made to broad psychological 'typing' of the simplest kind, it being admitted

that it is possible to go very much further in this respect than will be suggested here.

Physical training affords a means of bringing into action the healthy 'urge to power' which all possess, although many deny that they have it, being misled by a sense of false modesty or a conscious or unconscious memory of repeated restrictions or failures in the past, &c. It is not of course the only means of restoring healthy vitality, but it is one of the most basic, most potent, and most healthy. It can promote strength (physical, intellectual, and emotional). It stiffens endurance, and the 'stronger will' can be utilized in other walks of life. The following illustrations are not fanciful but psychologically grounded.

Practice of such apparently different activities as weight lifting, mountain climbing, hiking, cycling, swimming, &c., confers both physical and psychological power unless used excessively, when the reverse is the case. Such activities imply methods of triumphing over the physical environment, and of drawing increased strength from the effort (as indicated in the earlier chapters). In the case of psychological weakness the appropriate remedy is often indicated on physical lines, the psychological benefit being no less real because it appears as a secondary issue. The realization of the more powerful musculature or the better co-ordination of the heart and lungs consequent on the training is reflected in the emotional part of the personality; the irritable nervousness of some neurasthenics—primarily due to an innate conscious or unconscious sense of weakness—disappears, because the underlying disease which caused the victim to fly that flag of distress has been cured and so the flag is hauled down. The triumph achieved increases self-confidence and diminishes fear.

I have deliberately coupled endurance with strength, partly because the second is of little value as a rule without the first, but more particularly because it has been shown in previous chapters how the body becomes tuned up

physiologically by suitable muscular exercises so that it works more economically as well as more effectively. The same should be true in the psychological sphere, but psychological hindrances sometimes come into operation. All athletes have not good endurance powers, but that is because their training was wrong—either physically and physiologically, or psychologically, or both. Sometimes the training has been too one-sided; sometimes physical conditions of the body are at fault; sometimes there has been psychological mal-development or incomplete adjustment. The amazingly interesting character of the prophylactic and remedial work of a medical adviser is indicated in that last sentence!

The essentials of good endurance from the physical point of view have been enumerated in previous chapters; the corresponding essentials on the psychological side can be deduced by analogy. Kipling's lines:

> If you can force your heart and nerve and sinew
> To serve your turn long after they are gone,
> And so hold on when there is nothing in you
> Except the Will which says to them: 'Hold on!'

imply in the first pair good all round physical training, and in the second pair the psychological consequence. The training of the second is for many persons only accomplished gradually, the objects to be trained being the 'good heart', the 'cool nerve' and the 'strong sinew' of the emotional part of the personality. Physical education can never be complete without attention to these reflections of organs and activities in the psychological sphere. Neglect of this has done much to discredit physical training with some who have deservedly disliked an occasional finished athletic product by reason of his character. They have overlooked the possible intellectual and psychological benefits so easily obtainable by a little forethought and later training, and have concluded erroneously that the culture of the body is obviously less important than that of the mind and soul.

Robert Browning knew better: 'Nor soul helps flesh more, now, than flesh helps soul.'

Physical training enhances skill and increases self respect; it provides openings for acquiring self-knowledge (if the medical adviser knows his job), and so paves the way for self-control which prevents many actions which lead to disease and unhappiness. It fosters abilities and confers a ready adjustability to changing or unexpected circumstances. The various exercises which are conducted with the body stationary or moving upside down have a valuable psychological influence which is not always recognized; moreover the difficulties experienced by some in gaining proficiency in them give sometimes valuable clues to the psychological as well as to the physical and physiological handicaps of members of the class. A similar adjustability to the vicissitudes of life is inculcated by the hiking and camping which are increasingly popular nowadays; this particular psychological benefit, however acquired, is not lost when the physical activities cease, as they mostly do with advancing age. After having been fully attained, this adjustability continues to influence the life in much the same sort of way as 'keep fit' exercises act on the well-trained physical body. But a little daily practice is required to keep in training physiologically, and most people get plenty of practice in the psychological counterpart even though but little afflicted by 'the slings and arrows of outrageous fortune'.

In physical education the natural tendency to combativeness (noticeable in the female sex as well as in the male and signifying holding one's own in the human environment) is linked healthily to team work and friendly competing, which in some respects are the sum and substance of life. This combination is one of the more important benefits, summed up in the term 'true sportsmanship'. It must be noted by the medical adviser that reluctance to take part in boxing, wrestling, and team competitions maybe significant of latent psychological impedimentswhich may only appear as serious handicaps

later in life. In earlier life their cause can be fairly easily traced as a rule, and the appropriate treatment be instituted. Any excessive combativeness is similarly apparent, and can be treated when the reason for it has been defined. The gymnasium and playing-fields are unquestionably of the greatest value in this connexion, especially now that the underlying psychological element in aggressiveness or in its opposite has been scientifically studied and practical remedial measures have been defined.

Another outstanding boon conferred by physical education is the strengthening of the spirit of comradeship; many only join a gymnasium in the first instance because they are feeling lonely in life and seek for friendship in joint activities. This fact is sometimes overlooked by some who are charged with the task of organizing athletic clubs, and in all cases the success of these institutions is largely enhanced when the point is borne in mind and definite steps are taken to intensify the natural comradeship. Such a development on a greatly increased scale would solve many of the greatest afflictions of life, including war.

These are just a few illustrations of the possibilities of psychological training which an instructed and skilful physical training expert, or in some cases a medical adviser, can expect to bring into reality. He must remember that growth takes time, and not be impatient—a manifestation of childhood! He must promote a healthy 'mass psychology' in his class or in his athletic teaching on the playing-field, which will benefit persons of different individual outlook. He will encourage general smartness as well as cheeriness, eschewing any tendency to 'go as you please' which has psychological as well as other objectionable features. Slackness of discipline is as soul-destroying as is martinet severity, and the drawing-room voice is as out of place in a gymnasium as is the barrack-room voice in a sitting-room or the shouting of a football crowd in a religious service; all carry the right meaning in the right place.

The teacher or leader will keep as his objective the class 'becoming' rather than 'being' good—a salutary check on ill advised personal criticism and a necessary reminder to mete out praise in due season as well as to find fault when necessary. All these matters are of psychological import. There are very few in any physical training class or other group of humanity who do not need and cannot profit by a kindly word of praise, even though at times undeserved! The man who says 'I rarely praise' betrays the fact that he has a real inferiority complex—or in simpler terms a jealousy (born of innate and often unconscious fear) of his human environment, and is therefore inadequately adjusted to it. Some in the class who are doing well actually do not realize it, and need that word of praise to correct a feeling of failure. Those who excel, and are becoming conceited, should not necessarily be 'taken down a peg' because it is certain in some cases that such conceit will be the manifestation of an inferiority complex which has been overcompensated, and the 'taking down' will only increase their difficulties in becoming better adjusted to their psychological environment, both internal and external. They can be encouraged to help others and led thus to destroy the tendency to fear or despise them. Active promotion of the team spirit is a well-known procedure in this respect; the team may be small to start with, but when once the idea has been accepted it can be applied to teams of increasingly large size until the whole world is recognized as one team.

Progression is another natural and vitally important component as regards the character of the training as well as of the individual. The motto of the class as well as of the individual person should be: 'the best is yet to be'. Next year's course should promise better things than this year's course; the reason for failure in some schools of physical education is the narrowness of outlook of the designer of the course and the teachers in it. This failure is too often overlooked because of the entry of new recruits. Numbers keep up

and nobody in charge of the class realizes that there has been a leakage of many who have become disgruntled by the lack of progression for themselves. They go away rightly discontented, because progression is a natural and essential factor in psychological as well as physical education. They form false ideas about the limitations of physical training as they have experienced it, and tend to turn others away from taking it enthusiastically as well as seriously. This is one of the great dangers of to-day. It is largely responsible for the present apathy as regards physical fitness.

Teachers and leaders should aim at keeping their eyes, during classes, on individuals as well as on the class as a whole, giving to each one what he needs in the way of help and not concentrating on those who seem likely to be most useful in displays. Nagging is usually wrong, though not quite invariably, but even the worst pupil is probably trying his hardest so far as his temperament and circumstances will permit; seeming slackness, bad work, and even hostility to the programme and the exponents of it may often be of psychological causation, and it is more valuable to the community to induce repentance and reform in these sinners than to forward the progress of those who need no repentance. Bad members of a happy hard-working family are seldom uninfluenced by the general tone, and those who were at first the worst often end up by being the best in the class or at any rate high up in it—a much greater triumph for the teacher than the successes won by pupils who by reason of their internal and external environment had so much less ground to cover and so much less difficulty in covering it.

Attempts must be made by teachers and leaders in physical education to devise a sufficiently comprehensive and elastic programme of training to suit all physical types and psychological temperaments. Anticipating for a moment some suggestions to be put forward later as re-

gards a rough and ready method of 'typing', see that the round-headed enjoy the work, that the angular-headed are given feats to accomplish, and that the oval-headed find occasions for thinking out or feeling the reasons for doing things. Do not expect those with very straight eyebrows and the usual physical concomitants to show much imagination nor those with very arched eyebrows, &c., to appreciate the benefits of the stereotyped routine which others find so beneficial. Realize also that two hours a week of gymnastics or a game on Thursday or Saturday afternoons will be of little avail in promoting physical health and joy in life if the remainder of the week is opposing the training. Learn the secret of inculcating good habits, and appreciate the dominating part played in this matter by psychological considerations. As regards correct and healthy posture and carriage, &c., remember the psychologist's discovery: 'For there is nothing good or bad but *feeling* (not thinking) makes it so', and aim at getting the right attitude to life recognized and accepted by all in the class.

Each member should gain, often unconsciously, the realization how his or her physical training enriches as well as disciplines life in the world. The fencer must be able to parry joyously the thrusts of misfortune; the footballer be taught to experience the joy of scoring goals by fair means; the vaulter to revel in the skilful and graceful surmounting of life's obstacles; the dancer to appreciate the healthy feeling attending rhythmical movements; the boxer to be cheerily patient in scoring points and in wearing down an opponent who is too strong or too elusive to be knocked out quickly; the long-distance runner to acquire the delight of endurance and of maintaining pace, rather than of ending a race; and the agility specialist to desire and acquire the ability to 'break fall' in his daily avocations as well as to tumble about enjoyably and profitably. These impressionist sketches may convey to some readers a real understanding of some of the primary, not secondary (!),

objectives of physical education for those who 'keep the end in view'. The leader who can inculcate such adjustments to life is doing very much indeed even for those who will never rank higher than second rate in actual physical achievements. Indeed, it is often these relative failures in the gymnasium or on the playing-fields who turn out eventually to be the greatest successes in life, and the best advertisers of the wisdom and skill of their trainers. Judge by the progress in 'becoming' (relative to physical, physiological, and psychological handicaps) rather than the immediate achievements. See that all realize the larger objectives of physical education, and gain a greater joy in being alive. It is in this respect that the modern systems of training can be so much more fruitful than the old, though we have still very much to learn from the classical Greek ideals and practices; in physical education as in other departments of life 'the best is yet to be'.

These two brief chapters have only given a glimpse of the place of psychology in physical education, but an attempt has been made to indicate its basic and scientific importance. It must be realized that there is a national as well as an individual psychological outlook, and that consequently great care must be taken in selecting those forms of physical activity which have found favour in other countries. 'More haste, less speed' is a salutary motto in this respect as well as in education generally.

XVII

POSTURE

SINCE 'posture is the basis of movement; all movements start and end in a posture' (Samson Wright, 1936), it would have been thought that in these modern days of science (not to mention this 'year of grace') there would have been freely available standards for judging good posture as contrasted with bad posture, so that any medical adviser or gymnastic instructor would have been enabled easily to state at once in any given case not only what posture was good or bad but in what the badness or goodness consisted. Unfortunately, no such standards are extant, as search through many books of physical education will show, and indeed some temporarily approved postures are physiologically and physically unsound, being judged by inadequate observation and often from only one point of view, i.e. back or front of the body. This complete neglect of the scientific approach vitiates much of the modern teaching of gymnastics (a term used here in its widest connotation), and in some cases renders it not only a waste of time but actually harmful—as will be indicated.

Be it realized, however, that few authorities (if any) openly deny the importance of posture, however much they ignore it in practice. For instance, in the Board of Education's *Syllabus of Physical Training for Schools* (1933) the following sentences appear, among others.

'The maintenance of good posture is one of the primary objects of physical training, and one of the chief purposes of this book is to show how correct positions of the body in sitting and standing and in the ordinary occupations of daily life may be made habitual. The outward expression of the results of such training and the ultimate test by which every system of physical training should be judged are to be found in the *posture and general carriage of the children*, not only during the gymnastic lesson but in the classroom and on the games

field. If the class or the individual stands badly there has certainly been some failure in the teaching; no teacher can be regarded as successful unless his pupils assume good bodily positions naturally and as a matter of course without evidence of strain or stiffness.'

And again, in connexion with rural schools, it is remarked:

'Though the children may have opportunities of being out in the fresh air and sunshine, and of exercising out of doors, they need encouragement to make the most of these opportunities. Their general carriage is often bad, their movements awkward and clumsy, for co-ordination is poor and their general habit of mind may be somewhat unresponsive. The teaching, therefore, should be *especially directed towards training a sense of good posture*, to developing co-ordination and thus correcting clumsiness and encouraging lightness, agility, and ease of movement, and to inculcating a sense of rhythm in movement.'

And finally, in respect of the indoor lesson:

'An excellent opportunity will also occur for *posture training*. The teacher will have time to discuss with her class in some detail the various points which go to make up correct posture and to bring to their notice the means by which individual faults may be corrected. The class should be given practice in the taking of correct posture or the children may be allowed to work in pairs, each child correcting the postural faults of her partner. Thus the time may be turned to good account in an intensive effort to raise the general standard of posture by securing the interest of the children and training them through mind and eye to an intelligent appreciation of what constitutes good posture and how faults may be eradicated.'

The italicized passages and the punctuation are as in the original.

These sentiments are unexceptionable, but the good results are by no means apparent generally in our streets, nor do they appear to persist as the child grows up. The faults may be briefly stated: children do not assume good bodily postures naturally and as a matter of course; in many schools of gymnastics, indoor or otherwise, very little interest is taken in the standing or sitting position, though more is given to carriage during movement, it being realized dimly that various failures in gymnastic attempts are caused

by faulty carriage of the body; the sense of good posture cannot be acquired by the repetition of exercises; and the details of the cause and cure of faulty habitual postures are insufficiently studied and understood even by the teachers, many of whom exemplify in themselves in the gymnasium or classroom the very faults they are endeavouring to correct in others! The scientific basis of education in good posture has not yet been sufficiently recognized, and a great deal remains to be added by further research to what is already known by the better instructed in this respect. Some of the main principles will now be considered. As a beginning attention must be drawn to the insistence of P. Wiles (1937) on the existence of a 'postural reflex', and the failure of teachers to realize that the establishment of a good 'postural reflex' depends on the absence of movement, and not the presence of movement, in a given part, e.g. the spine—a fact of basic importance.

In *Health and Muscular Habits* (McConnel and Griffin, 1937) such notes as these will be found.

'It is a great mistake to think that our aim in physical training should be to teach control of the body by the will. . . . Instead one should arrange for the desired action to happen automatically in the first place and, if necessary, bring it under the control of the will power later. This may sound difficult, but it is the natural sequence of events, and is usually the best plan.'

Again:

'As regards the commonplace movements of everyday life, our attention should only be attracted by mistakes or irregularities. For example, we should certainly not attend to how we are sitting, but our attention should be free for other things when we are sitting correctly. We should be awakened to the fact that we are not sitting correctly by having our attention distracted.'

And again:

'The individual must: (1) have an intelligent grasp of the good and bad habits, appreciating the various tasks of the working parts concerned; (2) know what the good and bad habits feel like, and recognize a change either way; and (3) realize the benefit from making a

change for the better. . . . A commonsense grasp of how the foot works, and what a faulty foot feels like, is of the utmost importance in helping us to recognize a faulty foot habit. . . . Having appreciated what the desired movement feels like, and having found out what circumstances encourage it, it will quickly be noticed how easily one falls into the habit of doing it in these favourable circumstances. . . . The conditions under which the desired action will occur can readily be extended, if too great a change of circumstance is avoided at first.'

THE SPINE AND POSTURE

One of the most common causes of bad posture has descended to us from our ancestors who lauded the ideal of the 'straight back', oblivious of the fact that, even if this could be achieved, there would be great cramping of the chest and abdominal organs with consequent deformities and disabilities. It is a most instructive, though depressing, sight which greets the observer who stands behind a gymnastic class which has been instructed to hold itself erect. The spinal curves assume fantastic shapes in some and obviously faulty alinements to the limbs and head, and these are still further exaggerated in the case of those who are told to 'hold your stomachs in'. The class may perhaps look all right from in front, but behind it seems to clamour for orthopaedic treatment! 'Hold your heads up' is another useful command to enable observers to detect similar deformities from behind. A protruding stomach may be due to a variety of causes, such as a tilted pelvis or faulty foot-hold, but is still by many instructors thought to be due invariably to weak or untrained abdominal muscles, and most futile and inappropriate treatment is advised. When medical advisers are recognized as an essential part of the staff of all gymnastic establishments, many of these harmful follies will be stopped. A drooping head is not always caused by weak neck muscles; it may, as has been shown, be of psychological causation and only be corrigible on psychological lines, but it may also be due to some faulty posture in which the feet and legs are primarily concerned,

the postural alterations above them being of secondary occurrence.

The spinal column is not straight. At birth it has two curves, both concave forwards (primary curvatures). In adult life there are four curves: the cervical, thoracic, lumbar, and sacrococcygeal. They help to break the force of shocks and to withstand vertical pressure in the erect position. The curves are maintained normally by the shape of the vertebral bodies, the intervertebral disks, and the tension of the ligaments which hold them together. It is clear that misguided efforts to straighten them out will lead quite possibly to damage of a chronic nature. The cervical curve is convex forwards; it is a secondary or compensatory curve, and is due chiefly to the shape of the disks. It develops during the first year of life, when the infant begins to hold its head up, becoming more marked about the eighth or ninth month when sitting up begins. The THORACIC CURVE is concave forwards; it is deepest at the sixth thoracic vertebra, and extends to the twelfth, where it merges into the lumbar curve. It is a primary curve, and is due to the shape of the bodies of the vertebrae. The LUMBAR CURVE is convex forwards; it is more pronounced in a woman than in a man, and in a youth than in an elderly person. It culminates opposite the umbilicus, between the third and fourth lumbar vertebrae or at the fourth, and extends to the sacro-vertebral angle. It is a secondary or compensatory curve, and is due chiefly to the shape of the disks. It appears a year after birth, when the child, adopting the erect attitude, lifts up its trunk, straightens out its lower limbs, and begins to walk. This curve makes its first appearance immediately above the sacro-vertebral angle, and gradually extends upwards as the lower limbs come more into use. The SACROCOCCYGEAL CURVE is the original lower primary curve, and is concave downwards and forwards. The vertebral column is often also slightly convex towards the right in the thoracic region, possibly owing to the

greater prevalence of right-handedness, but more probably owing to the pressure exerted by the upper part of the descending aorta. When this curve is well marked, compensatory curves appear in the opposite direction above and below it (*Cunningham's Textbook of Anatomy*, 1937).

It is obvious that any one who sets himself to correct the shape of the human form must know the normal state, and the range of variations from it which can be considered normal, taking into consideration the changes (not always unhealthy) induced by occupational and other habits. The spine has been dealt with in detail here because there is great ignorance about its part in the maintenance of posture, and because it is the fixing point of many of the great muscle systems of the body. The note may be added that faulty function of the spine is most often not due to 'stiff joints' but to faulty functioning of the muscles. Habitual errors of muscular action tend to the shortening or lengthening of the vertebral ligaments, but the muscular fault needs attention before the secondary ligamentous changes are dealt with. Diseases of the bones and joints are relatively rare (though frequently blamed) in comparison with faulty muscle habits in cases of bad posture, and much treatment fails in its effect because this point is insufficiently recognized. Stretching these ligaments and muscles is not the correct line of treatment; in the case of the muscles attention paid to their antagonists is often required, because the consequent relaxation of the shortened muscles or ligaments coupled with their more natural use brings about the desired result. The term 'remedial gymnastics' (other than when employed by instructed and experienced operators) is rightly alarming to the medical adviser, because many well-meaning but ignorant gymnastic practitioners are doing a great deal of harm to human bodies to-day as well as to the noble cause of physical education. Specific references will be made later on to the anatomy concerned in the physical education of various parts of the body.

PHYSIOLOGICAL CONSIDERATIONS

Leonard Hill (1935) points out that the erect posture is maintained by the action of the brain and the muscles, the latter securing the balance of the body in various attitudes. The weight of the body is borne by the bones and ligaments, and thus fatigue is obviated. In man the maintenance of the erect posture is an effort, for the centre of gravity is easily disturbed, and the muscles must be frequently called into action to maintain the desired position. The head is balanced by the muscles so as to rest on the top of the vertebral column. The centre of gravity lies in front of the joint; thus the head of a sleepy person nods forwards, and the neck muscles must come into action to prevent this, when wakefulness is desired. The centre of gravity is situated near the front of the last lumbar vertebra. A plummet line suspended from the centre of gravity in the erect posture would pass a little behind the line which joins the two hip joints. Thus the trunk tends to fall backwards at the level of these joints, but this is prevented by the strong ligament which passes from the pelvis to the femur across the front of each joint and locks it, the muscles passing from the trunk to the thighs having to exert but little effort normally in balancing the body upon the heads of the thigh bones. At the knee the plummet line passes through a line joining the posterior parts of both joints; the weight of the upper part of the body thus presses upon the flat articular surfaces of the tibiae. The great extensor muscles in the front of the thigh prevent the knees from bending and the body from falling backwards whenever the balance is disturbed. The check ligaments which lock the femur and tibia together prevent the knee from being over-extended or bent to either side. In the position of 'attention', the plummet line passes slightly in front of a line joining the two ankle joints, and the body is kept from falling forwards by the action of the calf muscles. The weight of the body is borne by the spring

of the arch of the foot, the balls of the toes and the heel resting on the ground. The centre of gravity must always lie over the base of support. Thus a man stoops when carrying a child on his back, but walks erect if it is sitting on his shoulders. He leans backwards and to the opposite side if the child is on his arm. An old man widens his base of support by using a stick, and thus stands more securely; younger children tend to stand with their feet wider apart than do adults, but with the same objective (L. Hill).

The foregoing implies a considerable amount of physiological activity, and it is obvious that psychological considerations are also involved, for example in responding willingly or unwillingly to the commands of others or the behests of the subconscious as well as of the conscious parts of the personality. The indifference hitherto to the elements in what has appeared erroneously to some to be a simple question, namely the maintenance of a natural and healthy erect posture as judged from the standpoint of the individual person, is largely to blame for the poor results which continue to attend schemes of gymnastic training, and must be swept away now.

It may be recalled that about 9 per cent. more energy is required to maintain the body in the standing than in the recumbent position. Benedict and Murschhauser (1915) found that one subject used from 226 to 242 cubic centimetres of oxygen a minute while reclining; 234 to 260 while sitting; and 228 to 293 during relaxed standing. This is the equivalent of an average use of energy of 1·14 calories during reclining; 1·19 while sitting; 1·25 while standing relaxed; and 1·3 while standing 'at attention'. It is clear, therefore, that good posture may not follow disciplinary measures, even though apparently sound, and that failure to obtain it may necessitate sometimes the skilled inquiries of the medical adviser rather than the sterner admonitions of the gymnastic instructor, while in all cases physical

education should be related to the labours of the day and the general stores of energy of the individual person. While as a general rule these can be ignored in actual practice so long as good results are following tuition or indulgence in sports and recreational activities, they assume immense importance immediately when progress slows down.

In this connexion reference must be made to various considerations discussed by Sherrington (1906 and 1915), Cobb (1925), and Fulton (1926); these are summarized in Samson Wright's *Applied Physiology* (1936). In the first place reflex muscle tone must be preserved; it depends on afferent nervous impulses from the sense-organs in the muscles and to a less extent on the impulses from the vestibular apparatus in the ears and from the eyes. There is no essential difference between the contraction which maintains tone and that which executes a movement. It may be recalled that muscle tone is kept up probably by a slow asynchronous discharge from the anterior horn cells of the spinal cord producing a partial tetanus which is economical and can be long maintained. The oxygen consumption and carbon-dioxide output of such muscle is only about 25 per cent. higher than that of completely paralysed muscle; thus it is relatively indefatigable, though higher centres in the nervous system may in conditions of stress, and as safeguarding measures, appear to relax muscle tone and induce collapse. Hinsey (1934) has stated that nerve-fibres from the sympathetic system pass only to the blood-vessels and not to the muscle-fibres. This point is of practical significance in dealing with questions such as those of fatigue and staleness.

The motor fibre tracts of the brain-stem concerned in the maintenance of posture (extra-pyramidal tracts) comprise the rubro-spinal, the tecto-spinal, the ponto-spinal, and the stibulo-spinal tracts; the last three lie chiefly in the antero-lateral columns of the cord, and are sometimes designated collectively as the antero-lateral descending tract

of Löwenthal, to distinguish them from the numerous ascending fibres in this region. It has been shown experimentally that the flexor position of the body is reflexly maintained, and that special innervation is necessary for the extensor activities; thus the dropping position adopted by the fatigued persons or for psychological reasons represents the cutting off for one or more various reasons of nerve-impulses, and the resumption of a desired posture is no simple matter in actual practice.

Stretching a muscle which has its nervous supply intact increases the tension in it—a fact to be borne in mind by those who advocate stretching exercises. There is a popular impression that the rectification of an unhealthily contracted muscle or group of muscles may be effected by stretching exercises and, worse still, that failure to achieve success at once calls for continuation and intensification of the stretching process. This is physiologically wrong, and may bring about real physical damage of an incurable type—in addition to psychological reactions of an undesirable kind. Members of a gymnastic class who 'slump' after a period of training are flying signals of distress; their muscles have been over-exerted or over-stretched. Healthy exercise is followed by a sense of exaltation and renewed vigour. There is no need to instruct members of a class to 'smile' while at work; if the physiological and psychological principles of the training are sound, they will do so naturally, and their failure to do so constitutes a radical condemnation of the method of instruction. Stretching of muscles is brought about naturally by the activity of their antagonists, and this fact must be remembered in all development as well as remedial work.

The various practical considerations which follow would be out of place in this book, but they should be found in all books of gymnastic training which are compiled on sound modern scientific principles. Reference may be made again, however, to the urgent and practical teaching of

Wiles (1937) and Sparger (1926 and 1931). Wiles writes, for instance: 'The lengthening of a muscle can be achieved by getting it to relax more fully.' He adds: 'To stretch a muscle, its antagonist must be made to contract against resistance and to continue to work against the resistance when the extreme of movement has been reached.' And again: 'Final correction of a deformity can only be made by establishing new postural reflexes. This can never be done by movement, but only by absence of movement, therefore exercises must be designed to keep still the parts of the body concerned.' It must be obvious that this is in frank opposition to the current and orthodox physical education methods in this country as well as elsewhere in the world, and calls for the most careful attention of teachers as well as of medical advisers. The blind must no longer lead the blind into the pit of postural deformity. To quote Wiles again: 'The regulation of posture is a function of the central nervous system which determines the *length* at which the muscles are habitually held; the *strength* of the muscles is of less importance.' If he is right, scientific considerations demand a radical alteration in physical education, which may result in better health, beauty, and strength of body in the community. (Greek statuary suggests that that people had grasped the right principles of training without realizing their scientific basis.)

Following the pioneer work of Pavlov (summed up in his last book, 1927) on conditioned reflexes, the principle of which had been foreshadowed by Leibniz (1714), came the great contributions of Magnus (1924 and 1925) and others later. Comments on these of practical significance will be found in Samson Wright's *Applied Physiology* (1936), including details of 'righting reflexes' and 'attitudinal reflexes'. Walshe (1923) has shown that complex modifications of postural reflexes follow alterations in the position of the head. As a point of practical interest it may be mentioned here in parenthesis that some medical advisers start the examination of a person

for postural normalities and abnormalities from the head, and work downwards; others, including myself, prefer to work from the foot upwards. It is necessary to have some system; very many faulty deductions have been drawn by those who have no such method of systematic observation, and there has been much too much loose talk by those who 'get a general impression' from looking at a person generally, which has done a great deal of harm to physical education as a whole as well as to individual cases in need of remedial treatment, whether gymnastic or medical. There is need of a 'physiobiogram' corresponding to Kretschmer's 'psychobiogram' (1934).

Samson Wright (1936) points out that regulation of posture depends presumably in the normal individual person on the appropriate co-operation of the various brain, spinal cord, and muscular structures (see diagram on page 34). It is concerned more particularly with the kind of discharge which emanates from the anterior horn cells, which are the convergence-point of numerous tracts such as the posterior nerve-roots and descending fibres from various levels in the brain. Some of these fibres tend to excite and increase the cell discharge, others to decrease or inhibit it. 'An algebraic summation of all these conflicting influences takes place; the anterior horn cell responds accordingly, controlling in that way the degree of activity of its related muscle-fibres, and consequently the posture of the part. We have still a great deal to learn, however, as to how co-ordination is effected, especially among the various higher levels of the brain.'

Herein lies much of the work of the medical adviser, who is little better than a 'quack' if he does not make himself acquainted with the present state of scientific knowledge and its rapid advances in respect of posture, and communicate to gymnastic instructors and others interested in physical education the practical conclusions which must be drawn as regards their work. It is possible that we have as yet only

a glimmering light, but even that is enough to reveal the darkness in which so many educational and recreational planning is going on, to the great detriment of the national physique, not to mention the great waste of time and the certainty of disappointment which are so foolishly being allowed to continue unchecked.

XVIII

FACTORS IN POSTURE

ALTHOUGH only some of the factors concerned in good and bad posture can be dealt with here, and these only incompletely, certain lines of physical examination, development, and corrective work should become apparent, and point the way to more extended practice and research. Enough attention has not yet been given to children, and adolescents and adults have almost been overlooked—a sad indication of how far we have fallen in this respect since the classical period. Even with the concentration in latter years on the health of school children, much remains to be investigated. For example, J. Allan (1937) points out the need of determining more exactly what physical changes are brought about by the school environment, and states that there is a growth in height during holiday periods, which 'may be largely attributable to a reduction of the mechanical pressure imposed on the compressible intervertebral disks by such activities as gymnastics, games, and athletics'—a conclusion which is open to some doubt since the postural attitudes adopted in class may also be factors in his findings, even if substantiated.

Reference may be made to the work of G. E. Friend; the research undertaken in 1931 by the National Council for Mental Hygiene, and embodied in a pamphlet entitled 'School Life and Nervous Instability'; and the various annual reports of the Chief Medical Officer to the Board of Education. Doris Odlum and G. Somerville (1937) suggest that more attention should be paid to the standards of height and weight for age in estimating the state of nutrition. To this it may be added that such considerations may also have definite postural connotations.

THE FOOT

Sir Arthur Keith (1929), discussing the history of the human foot and its bearing on orthopaedic practice, reached the following conclusions amongst others. The human foot has been evolved from one which was prehensile, and function rather than form has to be studied in order to trace aright the sequences of changes. The arch is safeguarded and maintained by the reflex postural action of muscles, ligaments being merely second-line defences; 'flat foot' results from a defect in this defence. The muscles mostly concerned are the tibiales anticus and posticus. (These should be carefully examined in relation to posture, and the treatment of defective posture.)

The grasping muscles—the flexor longus digitorum, flexor brevis digitorum, the flexor longus hallucis, and the accessorius—have become subservient to the static needs of the human foot. The loss of the prehensile action of the big toe and its incorporation in the plantar arch were brought about by adduction of the outer toes to the big toes, and not vice versa. The short muscles of the big toe assumed the new and important function of maintaining the static use of its phalangeal part. There was a retrocession of growth affecting the external or plantar limb of the prehensile foot associated with a progressive growth in its hallucial limb. Mass of body has been the most important factor in bringing about the later changes of foot in the higher primates. (Has this process stopped yet, or are we still concerned with 'feet of clay'? If so, postural adaptation is not complete, and we may expect to have difficulties in securing correct posture, however defined; the prime cause of these difficulties would be then in the foot and not in the shoulders or head!)

Man is the descendant of an anthropoid of massive body, and not of a pigmy. D. J. Morton (1922, 1924, and 1927), however, holds that 'the term balance as applied to the foot

structure does not refer to muscle activity, but to the arrangement of the bones and ligaments which furnishes a stable base upon which body-weight can be supported with the least demand for muscular exertion and propelled evenly balanced upon the lever axis'. Keith argues against this view. He also defines five functional as well as evolutionary areas on the plantar aspect, namely the heel, external plantar area, external plantar pad, arch area, and thenar pad; irregularities of walking can be understood in many instances by bearing these in mind. 'As we step forwards, the heel and external plantar areas are the first to come in contact with and gain support from the ground. As our weight moves forward on our foot and we prepare to step off, the stress falls on the external plantar pad and then, as the final impetus of the step is taken, it falls on the hallucial part of the plantar pad.'

If the base of a column is faultily founded, no amount of rectification above it can do other than introduce new faults of a compensatory nature into the column, and these in their turn will result in fresh faults. The only sound treatment is that which is directed to the primary cause. A great deal of breath is wasted on admonishments against rounded shoulders, protuberant abdomens, and sunken heads which are often local symptoms of defects of development or acquired malformations lower in the body. Correct diagnosis is essential before any curative measures are undertaken, and the general rules of gymnastic instructors, being not infrequently inappropriate to the particular person, may be not only futile but actually harmful, despite the highly laudable intentions and keen interest of these teachers. The neglect of the intrinsic muscles of the foot is a case in point.

While the subject of the foot cannot be dealt with here in detail, it affords one of the many obvious reasons for appointing keen and instructed medical advisers to the staffs of physical education authorities and centres and for prosecuting research more actively than has been the case

hitherto while recognizing that there is already a great deal of knowledge available for gymnastic instructors and others about the correct functioning of the human body. The following details about foot action are taken from *Health and Muscular Habits*, 1937 (McConnel and Griffin).

Bad foot habits which have postural consequences include: sitting with the heels drawn backwards under the chair with the toes turned up and the soles stretched; sitting or lying barefoot with the toes folded over against the soles as when clawing; curling the toes under when standing or walking so that the nails come to the ground, and drawing the toes back so that the joints press up against the uppers of the shoes; using the pads of the big toes insufficiently; standing with the forepart of the foot turned outwards in relation to the leg, and with the heel at a slope; and standing with the legs leaning forward over the feet so that the hips are too far forward. Some of these faults are referable to the evolution of foot action in the growing child and adolescent, and are obviously comparable with the racial evolution traced by Keith. Their treatment must be directed along the lines which will forward the arrested or slowed developmental process. It must also be realized that many of these and other bad muscular habits consist of performing a normal action in abnormal circumstances.

The importance of the full functioning of the small intrinsic muscles of the foot is a commonplace with every practitioner of orthopaedics or massage, but is too often overlooked in practice by the instructor in physical education, who does not realize that the shape of the foot is preserved by the correct functioning of these muscles when the foot is called upon to carry the full weight of the body, especially during some exercises. These muscles draw together and narrow the forepart of the foot, and the outward sign of their action is a well-developed longitudinal crease between the ball of the big toe and the outer portion of the foot—a most valuable diagnostic criterion of

functional efficiency. Curly toes indicate that the short toe muscles are being under-used, and the long ones excessively used. If the toes do not take any weight, the sole is likely to become bruised in jumping, a not infrequent complaint in the gymnasium. Some persons do not realize that walking is a rolling action of the foot forwards from the heel to the toes, which, indeed should seem to attempt to grip the ground at the moment of leaving it, even when leather shoes are being worn. An attempt to secure this habitually will be found to be noticeably comforting, and to improve the carriage of the body.

There should be a rotation of the leg on the fixed foot in walking so that the knee-cap faces inwards or outwards slightly, without the foot slipping on the floor; the heel rocks over inwards slightly so that the lower corner of its inner side comes into contact with the ground; and the toes remain almost stationary while the part just below and in front of the inner side of the ankle bone bulges towards the other foot. In healthy subjects this threefold movement can be seen during marching if no foot covering is worn; much of the value attachable to marching exercises is negatived by the practice of them in shod feet, the observer being often rendered oblivious thus of the presence of bad habits which handicap efficiency as well as grace. The Greeks were wiser.

The leg must not rotate in the air, and the knee-cap must face forwards. The preliminary raising of the leg must not be due to muscles which pass forward to the upper surfaces of the toes, nor must the toes be drawn backwards so that the nails strike the ground later—a common cause of corns or thick skin where the prominent toe joints press against the uppers of the shoes. Faulty muscle habits as well as faulty footwear are to blame very often.

There should be no outward turn of the foot during the forward swing of the leg; this sometimes is due to the faulty carriage consequent on general muscular weakness,

especially of the thigh muscles. The heel should reach the ground in an almost upright position, and there should be no wearing of the heels of the shoes on the outer side at the back. The inner border of the foot should be stable, and there should be no splaying out of the big toe. Feet should feel flexible; those which do not do so are afflicted by bad muscular habits. Pressure round the back and sides of the heel should be even. Walking on the outer border of the forefoot is an evil practice. Very little pressure should be felt in the foot in other parts than those mentioned; such pressure is an indicator of incorrect muscular action, and it should be remembered that one such faulty action leads to another until eventually gross failure of the foot function with consequent deformity may ensue.

These are some of the commoner muscular bad habits which initiate bad carriage and posture, and fuller details about them are given by McConnel and Griffin (1937), who discuss their diagnosis and treatment, and summarize the essentials of good posture when standing. They point out that modes of breathing may determine posture as well as be affected by it; they as well as the eyes and head, neck, shoulders, arms, and hands have an influence on the posture of the pelvis and the lower part of the trunk.

PELVIS

It is important to realize that the tilt of the pelvis, forwards or backwards, is another real factor in the determination of posture. Faults here will render useless any attempt to create good posture until they have been corrected. The way to detect them is easy (McConnel and Griffin), but the possibility of their being originated by errors in such distant parts of the body as the eyes, head, and feet, should never be overlooked when attempting rectification. Neglect of the pelvis when lifting weights is common, and easily leads to persistent errors of posture. Shortening of the pectoral muscles is another cause of pelvic tilt, as also is any other

agency which leads to such restriction of the shoulders (such as a too tight waistcoat, &c.).

P. Wiles (1937) describes a new instrument for measuring pelvic inclination, termed the 'pelvic inclinometer' and made by Down Bros. The points taken for measurement are the upper border of the symphysis pubis in front and the level of the posterior superior spines behind. No mention of posture is made to the subject unless the one adopted is obviously forced. The angle in 'normal' adult males is said to average 31 degrees, and in females 28. In children it is somewhat less, but it increases up to 11 years of age when the adult level is reached. Deformities are classified on the basis of their two principal components—variation in pelvic inclination and the presence or absence of a dorso-lumbar kyphosis into four types: (1) lumbar lordosis; (2) sway back; (3) flat back; (4) round back. In cases where the pelvic inclination is increased, treatment is concentrated on the glutei, the patients being told to 'tuck their tails under them'. Treatment on the same lines is detailed by McConnel and Griffin (1937).

Excessive hollowing of the back can often be seen in gymnastic displays in which the distinguished audience is facing the class, and indicates that good movements or expert feats have been attained at the expense of the posture, and that the unfortunate performers may suffer in later life. Lindhard (1934) has issued a most salutary warning against these displays, and has shown how they tend to debase healthy athletics in more ways than one. Here I need only emphasize the tendency to please the crowd (so as to obtain money for physical education) at the expense of that individual treatment and education which is essential if the national health and fitness is to be improved. Many of the best gymnastic practices are not spectacular, and therefore do not draw large crowds, while many of the most spectacular are evil in themselves from the point of view of promoting good physical development. There is also a

tendency to select the best performers and to concentrate on their training, while the rest of the class are relatively ignored and are allowed to drift out of it unregretted. If prizes were awarded for individual development in respect of healthy natural posture and carriage as well as gymnastic achievement, and less glamour was attached to stunt displays, the whole nation would benefit.

SPINAL MOBILITY

The useful series of tests for spinal mobility which was devised by K. A. Knudsen is to be found in Galloway's book (1937) and is briefly as follows. The subject bends down and touches his toes, when the spine should form an unbroken curve from the first dorsal to the 5th lumbar vertebra, flat or concave areas indicating local immobility. He then raises his arms forwards above his head, and presses them back as far as possible, when they should form a straight line with the trunk, and the spine should become straight. In the stretch position the signal furrow should be unbroken and of even depth, local convexity or shallowness indicating stiffness. Then follow trunk bending sideways (with measurement of the distance of the finger-tips from the ground) and trunk rotation in the sitting position (with measurement of the angle through which the head moves). For more details, reference should be made to Knudsen's *Textbook of Gymnastics* (1937), in which there are suggestions for breathing-exercises, &c. In this and other books of the kind postural reflexes receive too little attention, and this must be remembered in adopting the various recommendations. Apart from this and some other controversial points of practice this book will be found of very great value to the medical practitioner as well as to the physical educator.

HEAD AND NECK

Attention to individual development is no new thing, but various opinions have been voiced as to the lines on

which it should proceed. For over forty years F. Matthias Alexander (see bibliography) has been teaching that head carriage is the essential agency of 'primary control' of more than physical posture, and that instinctive misdirection of this part of the body leads to faulty physiological and psychological effects.

In his Arris and Gale Lecture for 1932 (unpublished) A. J. E. Cave, now assistant curator of the Museum of the Royal College of Surgeons, defined an anatomico-physiological entity—the 'cervico-cranium'—a mechanism consisting of the skull and first two cervical vertebrae, which was kept closely associated by special ligaments and specially differentiated muscles in the sub-occipital region. He has discussed the anatomy more in detail in various contributions to the *Journal of Anatomy* (1930, 1931, and 1934). A. Murdoch has suggested that these muscles (rectus capitis posticus major and minor; superior and inferior oblique; rectus capitis lateralis; and rectus capitis anticus major and minor), which arise from the atlas or axis and have cranial insertions, are concerned with intricate movements of the atlanto-occipital and atlanto-axial joints and thus influence the vestibular apparatus in the petrous bone which is so closely concerned with the act of balancing the body and the postural changes related thereto, forming a kind of 'muscular control centre' comparable functionally with the respiratory, cardiac, &c., centres in the brain. Their action, he adds, may form the anatomical basis of Alexander's technique, and further investigation along these lines is most strongly indicated in view of the good results which have attended the use in practice of this technique, as noted by P. Macdonald (1926, 1928, and 1932), A. Murdoch (1928), J. E. R. McDonagh, A. Rugg-Gunn (1931), M. Douglas, and others.

Alexander anticipated in practice the experimental work of R. Magnus (1924), which indicated that the primary control of the animal mechanism in action depended on the

carriage of the head and neck, and that the tone of the muscles in this neighbourhood conditioned the tone of the remaining musculature of the trunk and limbs. It is thought by some, also, that this conception governed some of the athletic and gymnastic education in the classical Greek period, since there is evidence forthcoming from the statuary of that period. He maintains that the direct drawing of the pupil's attention to the postural faults which require correction brings about a contraction of the muscles concerned and consequently accentuates the evil. In *The Use of the Self* (1932) he describes the evolution of his technique; use and functioning in relation to reaction; the golfer who cannot keep his eyes on the ball; the stutterer; and diagnosis and medical training, which show *inter alia* that his system is to be regarded as much as a means of physical education as a branch of remedial gymnastics. It may in some measure, therefore, be considered as a practical extension of the work of Magnus and others, and its psychological connotations are as important as its physical bearing.

The frequent failure of physical training on the usual lines to bring about good posture as a habit has been repeatedly noted, and medical advisers as well as gymnastic instructors and the organizers of sports and games would do well to consider very seriously the necessity of studying closely the 'indirect approach' as a vital part of physical education. S. Kinnier Wilson (1928) states that 'the apparatus for the auto-regulation of attitude must be in being if control excitations are to effect movements and acts'. If this is so, a vast new field for experimental research as well as for practical work on the playing-fields or in gymnasia lies open to us, and the future welfare of humanity depends on the recognition of this fact.

XIX

VOCATIONAL PHYSICAL EDUCATION

PHYSICAL characteristics as well as sex and age ought to be considered in physical education much more than they are at present. In this way it would become much easier to render sports, games, and gymnastics more popular and widely accepted, with consequent improvement of the health of the nation. Some recognition is extended to the last two already, even though temperamental proclivities remain mainly paramount. Doubt has been frequently expressed whether athletic pursuits in youth may not hinder more than help in later years the woman in child-birth, but the scientific evidence in this respect is rather conflicting. Many will advise children and youths against attempting feats of endurance beyond their physical powers, though even here many mistakes are made owing to ignoring the scientific facts in individual cases.

The almost complete neglect of taking into account the personal physical characteristics in advising individuals or age-groups is, however, entirely unjustified, for there is extant a good deal of real evidence in this connexion, and speculation has indicated lines along which further research may proceed with prospects of good results, even though conclusions may sometimes—as in other branches of science—be drawn prematurely on inadequate data. With this threefold line of guidance, namely age, sex, and physical characteristics, it is possible to formulate some general rules of practical value, but it must be remembered that the human frame is very adjustable, and that the most obvious conclusions may sometimes be upset by psychological factors which have been overlooked. In practice, however, this does not matter. We can more easily allow for excep-

tional cases, and no harm is done by giving advice tactfully even when it is rejected, sometimes rightly.

AGE-GROUPS

It must be remembered first that age-grouping must permit of exceptions; some are physically, physiologically, or psychologically older or younger than their chronological age, and must be dealt with in accordance with the individual circumstances. For instance, some children have their development healthily quickened by being included in physical education classes which at first seem to be beyond their capabilities judged on chronological data; others are discouraged and retarded. The same is true for adolescents and adults.

There can be little doubt that the change in a child's life when the school age begins has still not received enough consideration. It is doubtful whether modern school desks are altogether satisfactory; it is certain that at that age, for some reason or other, faulty posture and carriage become very noticeable, and that faulty muscular habits appear. If unobserved and unchecked, these habits will persist and be difficult to eradicate. They may have no relation to considerations of nutrition or of adequate exercise of the right kind, and more research is very definitely required in this sphere. The importance of this matter is immense, since when a child has learnt to feel the benefits of good posture and carriage it will not abandon them in later life without a great struggle, and will be much more amenable then to training on the right lines. Further details would be out of place in this book, since all that is here attempted is to emphasize the scientific basis in physical education, not to discuss the resulting conclusions in full detail.

Be it remembered, however, that work in school in the sitting posture tends to cramp the processes of circulation and respiration, to interfere with the then normal diaphragmatic mode of breathing as well as the upper costal movements.

It also impedes the circulation by interfering with deep breathing, which is associated with muscular activities—a handicap which is more apparent in some children than in others, but is inadequately compensated by periods of games in the open air or by keeping the windows of the class-rooms open. Digestion and the other metabolic tissue changes in the body are similarly handicapped.

Between the years of 6 and 9 an attempt should be made to activate the large muscle groups and to enhance *joie de vivre* as well as to encourage gently the emergence of will power. From what has been stated in the previous chapter, the value of exercising in bare feet will be obvious—provided that the teacher knows how to detect and check the beginnings of bad foot habits. It may be useless otherwise! Very inadequate attention is given at this stage and later in childhood to the enforcement of adequate mental and physical rest; yet it is well known how bad many homes are in this respect, and much more should be done in the way of educating the community. Even if twice as much attention was given to the problems of over-work and fatigue (including mental over-stimulation) as is given to those of faulty nutrition of all classes of the community and at all ages, it would not meet the requirements of the present day. Much longer hours of sleep are needed in the early years of life very often, though in later years the complaint is rather that there is too little sleep during the week and too much at week-ends—a very faulty attempt at compensation which has unfortunate physical as well as psychological consequences.

Rhythmic exercises should not predominate in the gymnastic work of small children who are healthy, being contrary to their psychological and physiological requirements; it has, however, an undoubted value in the case of those whose nervous systems are unstable, but needs to be scientifically prescribed to suit the special difficulties. Active games are best for the ordinary child, and the *Syllabus* of

the Board of Education (1933) contains a vast assortment suitable for the various periods of the school age.

The more difficult games come into use in the 9 to 12 age period, when greater opportunity for activities of the developing heart, lungs, muscles, and nervous system are necessary. The importance of the right sort of clothing for these and of the provision of shower baths with hot and cold water is receiving nowadays increasing recognition, the many important duties of the skin having been at last discovered by the rulers of the community, although they have still much to learn, as has the general population also in this respect. Running, jumping, throwing practices, and games are of especial value, and at least one hour a day should be set aside for them, the 'loss' of time being more than compensated by the increased intellectual as well as physical vigour which will result. Considerations of posture and carriage should receive special care. In the *Syllabus* of the Board of Education (1933) it is remarked: 'In many schools as many as 75 per cent. of the children not only stand badly but have one or more of the minor deformities commonly associated with mal-positions.' Easy exercises involving skill may also be used, and some authorities believe that apparatus work may be started with profit at this age.

The age-group from 12 to 15 is in boys the pre-pubertal period, but in some of the girls puberty has already arrived towards the end. This difference is of practical significance in indicating the beginning of differentiation between the sexes as regards physical education. Generally speaking, this age-period is characterized by the rapid development and growth of the heart and lungs, while the blood-vessels remain relatively small, consequently such activities as races and sports have now a special value. In Germany endurance hikes are commended also, especially in the later years of this period. Schmidt and Sputh (1931) recommend vigorous poses to aid posture, but it must be remembered that the formation of the healthy muscular habits on which good

posture depends requires something more than transient poses. In the case of boys, vaulting, jumping, and hurdling may well be begun. Girls with a broad pelvis and relatively short legs require different development exercises from those with other physical formation, and the incidence of menstruation further modifies the question, though it must not be thought that vigorous muscle work for them at this age is contra-indicated. It is probable that some cases of chlorosis are precipitated by unwise and unnecessary limitation of muscular activities in the open air. Swimming as a form of physical training for girls is increasing rightly in popularity.

The effect on maternity of physical activities during adolescence in girls has been discussed by Lady Florence Barrett (1937). She denies that the pelvis may thus tend to be flattened and that the muscles of the pelvic floor may be weakened. Securing of good posture prevents lordosis. Muscular co-ordination prevents also overstretching of the recti abdominis muscles, while relaxation of the perinei can be taught indirectly. All exercises which promote suppleness and free movements at the pelvic joints are commended. She added that few girls breathed easily and naturally without special instruction. Correct inspiration and expiration methods might even result in the future in the abolition of maternity belts. Deep breathing, involving the contraction of the abdominal muscles and the descent of the diaphragm, should, she maintained, be learnt in youth.

Before passing from what in Great Britain and Ireland is generally known as the school age reference may be made to the discussion of posture in the *Syllabus* of the Board of Education. Some grounds for doubt exist as to the scientific validity of some of the statements, and further research is definitely indicated. But a few extracts from this publication will tend to elucidate some practical points. 'Curative or remedial exercises should be given only by persons

having suitable training and qualification. They cannot safely be used by any one else.' Such qualifications must include a sound knowledge of the scientific basis, as well as of departures from a definitely understood 'normal'—the study of a lifetime, and emphasizing the need of caution. The *Syllabus* enumerates the chief groups of muscles involved in the maintenance of correct posture as the muscles of the ankles and feet; the knee extensors; the hip extensors (buttock muscles); the intravertebrally acting muscles; the abdominal muscles; and the neck muscles. The 'indirect approach' to the correction of irregularities of action of these has been indicated as essential by McConnel and Griffin (1937), and much disappointment would be avoided if it was realized that the concentration of attention for a moment or two on some muscular activity will not secure habitual benefit unless the cause of the fault is removed and the feeling of greater ease resulting from good posture is appreciated by the child. 'Many children stiffen the whole of the body when taking a position, or when simply trying to stand well. This over-emphasis is itself a malposture, it is a waste of energy, and is bad training for the child.' Indeed it leads to habitual bad posture, and must be avoided. The same is true of adolescents and adults in ordinary life, as can be seen easily enough in any gymnasium by those who have eyes to see.

Schmidt and Sputh (1931) detail the athletic practices suitable for male adolescents and youths as follows. Between the ages of 15 and 17, with the extraordinary growth of the heart and the relatively slow development of the blood-vessels, there is generally an increased gain in height, and physiological considerations emerge with practical implications. Vigorous athletic pursuits are now indicated, naturally commencing moderately but continuing progressively. (In some cases too much speed in progression is attempted, especially by those who, having been relatively physically untrained between the ages of 14 and 18,

suddenly attempt to make up for lost time by a spurt when joining some athletic club in the late teens. Many are the cases of failure to adjust so suddenly which could be easily remedied by a little expert advice based on the physiological state and inculcating graduated training suited to the individual. The medical adviser can be of immense service here to the individual enthusiasts and to the community. Many who lose interest in athletic pursuits at this time are simply cases of 'more haste, less speed', and from this arises an unhealthy trend to be spectators at sports, &c., rather than to take an active part in them.)

Deliberate efforts should be made by instructors to popularize exercises and recreative activities which promote strength, skill, daring, and endurance. Apparatus work affecting the shoulder girdle is good for the development of the chest and shoulders, and the benefit persists throughout later life. Exercises of speed are most valuable during the 16th and 17th years; the good of rowing should not be forgotten, and the Scout Movement has brought out of late the great possibilities of hiking and climbing. From 17 to 20 all these activities can be pushed with advantage, and in that period the stage of physical development should be reached which has been immortalized in some of the Greek statues, particularly the Ephebos of Antikytheres. Special attention must also be paid to the adverse influences of occupation and insufficient sleep. There should be no such state as 'the awkward age'—a term which has done untold harm, both psychologically and physiologically. Any physical or emotional phenomenon which appears to justify such a conception is an indication of maldevelopment of some kind, and is an open condemnation of those responsible for the earlier training of the unfortunate victim. No amount of classical posing will correct it, but it can easily be prevented if education is planned on scientific lines. It may be added that many of us frankly disagree with the condemnation of bicycling by Schmidt and Sputh: 'before

the 14th year it is an exercise of questionable value because it induces young people to assume a bad posture (round back), it decreases participation in wholesome walking and tramping, and finally it offers many chances for over-indulgence'. If the developmental training otherwise is on sound scientific lines, these faults will not appear.

The main principle in devising recreative work for the adolescent and adult who is being hampered by occupational conditions is to encourage the use of those muscles which are inadequately employed in daily life and to promote the development and healthy functioning of those physiological activities, as well as intellectual ones, which are necessarily rendered relatively inactive for a great part of the day, bearing in mind the necessity of securing enough rest, which does not in all cases mean physical or intellectual inactivity. The emphasis laid by the Greeks on 'balance' and 'moderation' is the important factor in such planning, the terms being taken in their full significance in respect of body, mind, and spirit.

From 20 to 30 or thereabouts is the period which permits the highest development of skill, quickness, courage, alertness, daring, and endurance through physical training. Schmidt and Sputh emphasize the fact that now, assuming a previous physical healthy education, there is little objection to specialization, provided that no one-sided type of exercise (such as fencing) is allowed to exclude others altogether. Many have thought that they have traced a tendency to a one-sided attitude on life generally in those who have become one-sided in physical activity, and have seen illustrations. This also applies to women. From 30 to 40 should be the time of fully developed manhood, the time of greatest strength and endurance; the adaptability for exercises of skill and agility has already decreased in most, and cannot be replaced by practice. The capacity for speed has already decreased, but this is compensated in such games as tennis by a much greater craftiness and ability to

foresee the next move of the opponent, or of life in general. Schmidt and Sputh think that the arteries begin to harden at about 40, and decrease the fitness for physical training, but this will be contested by many physicians; individual as well as racial factors are concerned in this, and there is little doubt nowadays that such a slowing down of vital activities is not a general rule, but is associated with other factors than those of advancing years.

One fact surely emerges from the foregoing considerations very clearly, namely that 'keep-fit' exercises cannot be standardized, and that therefore there is a certain danger in advocating them too enthusiastically. Each person should have the knowledge, or the accessibility to scientific advice, as to what exercises are most suited to his individual requirements at the particular time. These requirements alter with different occupations and are not the same for different temperaments. They also change with age. The modern tendency to try to devise short cuts to physical recreation or physical development is unscientific. The factors of physical structure to be dealt with in the next chapter are also significant in this respect.

So much depends, anyhow, on what degree of physical development has been attained early in life. He who has, for example, specialized in speed, endurance, and skill practices, such as football, for a sufficient length of time, and has then dropped all physical activities for a period of years, will find on attempting to resume them that he can relatively quickly win back his capacity for bearing an 'oxygen debt', his heart, lungs, and nerves not having lost altogether their ability to co-operate, and indeed being manifestly superior to those of the man who has had no such athletic past. His 'keep-fit' work will be of a very different kind from that of the man whose sport was of some other kind. While one man will gain good from a daily five minutes' course of free-standing exercises, another will profit as much from swimming twice a week, another from

golf at the week-end, &c. Those who have been so unfortunate as not to train their bodies in youth will have to rest content with relatively poor responses to physical training undertaken in later life, for their developmental period has to some extent passed. Yet it is true that all can become physically better than they are by paying attention to their physical body, for even in this respect 'it is never too late to mend', but they must approach this task cautiously as well as hopefully, and be guided by the physical success slowly achieved rather than by any emotional reactions which may at first depress or elate them.

XX

PHYSICAL TYPES

FROM time immemorial the existence of various physical types of humanity has been suspected, and attempts have been made to define them with various purposes in view. In this book the subject is raised in order to stimulate a further examination of the possibility, because vocational physical education would be placed on a much sounder footing if such typing could be established as a practical proposal in a considerable majority of cases. Some of us who have used such typing in practice have found it of immense value, but the time has not yet come for dogmatism. The objectives of such typing are: (1) to facilitate recognition of the latent physical powers in any individual person; (2) to define how far physical development in any one and all its aspects has advanced towards completion in any person as well as in the general and local community; (3) to guide along the natural lines those who are responsible for prescribing forms of training or 'keep-fit' work so that already existing propensities may find greater opportunities of development and that lines of training which, though approved elsewhere in the world, are unlikely to be acceptable locally for physical reasons may be avoided; and (4) to establish more clearly the physical, physiological, and psychological principles which appear to be concerned in the development of different races as well as of the right lines of adjustment of groups of persons to conditions of industrial employments and general life.

A great deal of knowledge has already accumulated, but here it will be best to indicate briefly some of the main conclusions which have been reached. This will indicate the lines on which future expansions of knowledge may be expected as well as the ways in which medical advisers and

physical training instructors may utilize the principles which appear to have been established already. The science of anthropology has been curiously neglected in the practical work of rendering mankind more fit to stand the strain of advancing civilization, and this neglect has caused some, including Professor Bragge, to wonder whether mankind can stand the strain of any more scientific discoveries. The difficulty appears to be that certain lines of scientific research have advanced out of proportion relatively to others, and the cure of the undoubted evils which have resulted is not to attempt the impossible task of slowing this progress, but rather to concentrate more on the laggard sciences. At present popular anthropology has been limited too much to hypothetical phrenology, which at its best is mainly empirical and at its worst savours strongly of quackery; yet phrenologists exist of the scientific order, and their work has been most unfairly ridiculed and most unfortunately ignored from the point of view of increasing the efficiency and happiness of individual persons and promoting the benefit of humanity—tasks for which they are exceptionally well endowed.

Kretschmer (1925) refers rather disparagingly to the French nomenclature of human physical types denominated: cerebral; respiratory; muscular; and digestive, but stresses the point that much excellent intuition lies behind this classification, and adds that the last two types reappear in the German classification as athletic and pyknic. His discussion of these French types, like so much of his other writing, is illuminating as well as discerning, and it may be noted at once that each one of these four types demands a different line of physical developmental training and a different line of 'keep-fit' work from that which is appropriate to the others. Men of reason, with big heads; eaters, with big abdomens; acrobats, with big muscles; and runners, with fine lungs, obviously fall into different classes from the physical education point of view.

Even if we agree with Kretschmer that the weak point in this grouping is that it is not followed out to its logical conclusions, and that various fanciful and unscientific conceptions creep in, we have to admit that a very much worse fault is to ignore such differentiation altogether—and this is the outstanding stupidity of physical education to-day. Various schools of thought have their enthusiasms and rivalries, few of them realizing the obvious truth that their narrowness disqualifies them from being of general applicability to the needs of the community as a whole, even though they have special value in special types of physique and physiological or psychological endowment.

CLASSIFICATION OF TYPES

At the beginning of this century, independently although almost simultaneously, Bernard Hollander in England and E. Kretschmer in Germany put forward a closely similar classification on physical lines which they found to be associated with psychological outlook. It must be remembered that these teachings were based very largely on experimental work. Thus Hollander (1901) cites an enormous amount of clinical and pathological evidence in support of his views as regards the head, while Kretschmer at that time was in no way backward in his determination to establish the extensive scientific basis which he was convinced merely awaited discovery in order to prove of immense practical importance.

Kretschmer distinguished three types: the 'asthenic', 'athletic', and 'pyknic', stating that this morphology was more noticeable in the case of men than of women. (From the practical point of view, it is by no means difficult to make the necessary corrections when examining the female sex. Obviously, it will be easier to detect the outstanding features of the different types in adults rather than in children; equally obvious is the fact that mixed types constitute the large majority of humanity. In the first case,

however, it is true in practice that 'coming events cast their shadows before'. In the second case it is usually fairly easy to distinguish the relative proportionate distribution of the physical elements characteristic of the different types, and so to assess the individual person as a whole.

Kretschmer, like Hollander, was primarily concerned with his anthropological and biological classification from the point of view of practical psychology. Others have used the classification for 'character reading' and child or adolescent as well as adult vocational guidance. In this book the classification is only considered from the point of view of physical education, but even so the subject is so vast that only an indication of the possibilities can be given.

Hollander, unfortunately, concentrated more particularly on the skull, overlooking the fact that the general physical make-up reinforced many of his conclusions. His defence of phrenology weakened his position in the opinions of the biased scientists of his time, and undoubtedly led him into certain assertions for which there was then, at any rate, insufficient scientific basis. By recalling that the head is part of the body and shares its general physical characteristics, it is frequently possible to get a point of departure for an assessment of the athletic outlook on life as well as of the physical endowment of any person, and by taking into account all the available physical evidence to give very sound vocational guidance—as judged by the results. Before detailing this practical work, it would be well to note the original classification of Kretschmer.

The 'asthenic' type is now more often known as the 'leptosome', or light-bodied type, partly because the word 'asthenic' gives an impression of weakness which is not legitimate in this connexion. The tendency is to height rather than breadth of body, narrowness of head, a rather flat chest, and poorly marked musculature. Schmidt and Sputh (1931), who discuss these types most instructively

as regards their relation to physical activities, point out that these leptosomes frequently become capable of achieving records, especially in running and jumping.

In my own work I prefer to designate them 'oval' types, as contrasted with the 'round' (pyknic) and 'angular' (muscular) types of Kretschmer and others. It is obvious at once that, if the observer can detect a physical capability of prowess in certain lines of athletic pursuits, it may well be that many of the pupils in a class have an unconscious trend in these directions arising from an innate capacity, and only await the awakening and stimulating influence of the medical adviser or instructor. The intense interest of this line of work will be instantly realized. I have found that 'two heads are better than one'—in other words, that the co-operation of the gymnastic or athletic instructor and the medical adviser working on his basis of scientific knowledge is most effective and enjoyable.

The 'pyknic' type is shorter in stature, tends to 'roundness' and plumpness, but often displays unexpected athletic powers. The 'muscular' or 'angular' type is more addicted to endurance forms of athletics. Schmidt and Sputh postulate other athletic types, such as tall and slender, and short and gracile with a decidedly sinewy body. I think that these are only variations of the three primitive types, but they differ admittedly very much in their character and attainments. These authors state that most of the participants in various athletic and gymnastic activities are 'well proportioned', some being tall and slender, others being more massively built. In this class they place also the small and middle-sized persons with well-developed muscles, a broad pelvis, short legs, lightly knotted muscles, a slightly rounded back, and a well-developed chest; they call this group the 'football type', although variations stand out as apparatus gymnasts and boxers.

These authors cast aside Sigaud's classification, which has been mentioned as the French one, and also Kretschmer's

classification; instead, they distinguish five types, namely: leptosomes, or light athletic; tall and slender; short, gracile, and sinewy 'football'; heavy athletic; and pyknic. This classification is certainly helpful, but it seems to some of us that it is too elaborate for practical work at the moment. Schmidt and Sputh, moreover, draw attention to the important point that the most splendid physique will be negatived by the lack of a desire for competition, or by physical disease. Before proceeding to certain practical deductions which are valid whatever classification is adopted, a simpler one may be mentioned with its psychological as well as physical connotations. The three groups are designated: (1) the Round; (2) the Oval; and (3) the Angular, these characteristics being easily assessed proportionately in the head, the hands and limbs, and the trunk, and the deductions as regards physical education being quickly made in many cases, although in some rather more time is needed.

THE ROUND TYPE

This recalls the pyknic type to some considerable extent. The head, face, body, and hands tend to be rounded, the limbs being rather on the short side, and the hands and feet relatively small. The muscles may be soft and flabby or well developed, and the abdomen tend to paunchiness. Bony edges and prominences are usually concealed by plumpness or muscular covering. The face is often large in relation to the rest of the head, and the expression is genial, peaceful, or even dull.

These people are usually chiefly interested in living comfortably their ordinary routine lives; their motto might be 'Let us live, while we do live'. They do not want to attempt feats or to pioneer, or to think about things, but rather to make the best of life as it comes. They are fond of comfort and prefer play to work, but are not necessarily at all lazy. They have often plenty of vitality which they enjoy working

off, but they cannot do well at an occupation or sport which they do not enjoy. They aim at being 'at home in life'.

From the physical education point of view the side they demand is that of enjoyment. Some make good wrestlers, shot-putters, and heavy athletes. Some of them are physically active in early life, and grow fat and sedentary later, with physiological disabilities which may result in definite disease. The beginnings of a barrel-shaped chest may be detected early in life, and practical conclusions can be drawn according to whether it is an isolated phenomenon in a differently shaped body or part of a general rounded body conformation.

THE OVAL TYPE

The face in this type is often mobile and expressive, small as compared with the upper part of the head, and broader at the forehead than at the jaws. The body tends to be tallish, thin, and small-boned. The limbs are slim, and may be on the small side, though the long-legged type is often seen. The hands and feet are often small and noticeably long in proportion to their breadth. There may be either a thoughtful and quiet demeanour, or a general impression be given of vigour and buoyancy.

These persons might have as their motto: 'Let us think or feel', rather than 'Let us work or play'. The dominant brain or emotions makes the body its servant, sometimes unhealthily so, and they need physical education more than they desire it for its own sake. In other sub-types, however, these persons produce very good athletes and gymnasts, devoting to it their thoughts as well as their feelings, their predominant character being 'at thought (or feeling) in life'. They like to design schemes or inventions for the angular type to work out and bring into being for the round type to enjoy. Their athletic ideals, when they exist, include running, the distance turning largely on their length of leg and its muscularity, those with long legs being less usually

successful in long-distance races if the body is proportionately long, though the reverse is true for those with long legs but short bodies. The same considerations apply to gymnastic pursuits, and can be easily worked out for individual cases by medical advisers or instructed gymnastic teachers. As will be shown later, some of the greatest problems in vocational athletic guidance are to be found in this group; it corresponds to the leptosome, and to the light athlete type of Schmidt and Sputh.

THE ANGULAR TYPE

Angularities may be due to bone or to powerfully developed muscles, and accordingly two sub-types can be easily remembered. The second includes the progressive pioneers in life; the first those who specialize at 'digging themselves in'. Some have high and marked cheek-bones, square jaws, and occasionally very prominent front teeth. The head is large and bony rather than fleshy. The shoulders and face are generally broad. The body and limbs may be on the large side, but small varieties of this easily recognized type are to be seen. On the average they are shorter than the oval type, and not so short as the round type.

Their motto might be: 'Let us get things done'. They usually love power in one or other of its forms, and like to take the lead in life. They welcome physical activity usually, and dislike restraint. They aim at achieving success by forcefulness or perseverance rather than by forethought or scheming; they would far rather push down a brick wall in their way than find a track round it. Their character might be summed up as 'at work in life', and they have a way of trying to force the round and oval types to follow their example! The application of this to physical training is obvious; these persons tend to be good at endurance running, for instance, and they are seen in numbers on football grounds as well as in boxing and wrestling contests.

A simple way of roughly differentiating these different types may be given. In this respect such a scheme of classification has obvious practical advantages over other more elaborate ones, even if it is not so susceptible of finer adjustments without the introduction of subtler points.

When examining any person for rough classification note the shape and contour of the head from all sides, and compare it with that of the body. Consider the relative proportions of the head, trunk, and limbs. Then decide which of the three types can most fairly be ignored. Next deal with the two remaining types likewise, and an order emerges; for example angular, round, oval. Now allot marks on a percentage basis; for example, the results might be angular 50, round 30, and oval 20. It is now possible to assess approximately the physical as well as the psychological capabilities of the person, and inquiries on this basis will be found to be time-saving as well as practically useful. Certain athletic activities can be left until last, while the tendency towards others is first taken up. Moreover, the reason why failure at certain gymnastic and other athletic achievements has occurred can often be explained on a physical basis, though there may be psychological factors concerned also.

As an illustration of the working out of this recognition of the part played in actual vocational guidance by the physique, the following anecdote is taken from the *Physiology of Exercise*, by Schmidt and Sputh. It may be premised, however, that such apparent rejections of advice at first have often some psychological basis.

'Let us cite two examples to show that a man is born for his sport: (1) A tall, slender, 16-year-old lad asked me what his best speciality would be. I answered him thus, "For the present you need all-round training but later on you will make a good middle-distance man." He laughed at me and said, "I am an out and out sprinter, and best suited for the 100 metre dash." A year later he was entered in the 200 metres, and two years later in the 1,500 metres dash. (2) The Physical Education Association (Turnlehrerverein) in Berlin issued a questionary. In the reply it was found that the tall slender men

with the so-called nervous hearts preferred middle-distance runs—a proof of the connection between build and attainment.'

To enter more fully into this question would fall outside the scope of this book. A practical scheme of recording physical characteristics is given by Kretschmer, and can be modified for classwork most usefully. Further details may also be found in the text-book of Schmidt and Sputh as well as elsewhere. It may, however, be added that these authors state that every sport requires its own definite body-build if proficiency is to result. In the long-distance run, besides the ability of the musculature to resist fatigue, the character qualities of persistency, determination, and will power to hold out are factors in bringing victory. Tall as well as short men, or slender as well as stocky men, may achieve very creditable records in 'dashes'. The physical type of the all-round athlete is characteristic; he is rather large, broad-shouldered, with narrow hips similar to the Greek Apollo type, who must be fit to hurl and jump as well as to run short and middle distances. The gymnast (tumbler or acrobat and agility specialist) is short with broad shoulders and small or narrow hips. The arm and shoulder muscles are markedly developed, powerful, and bulky, while the hips are narrow, and the legs are comparatively light. This is explained by the fact that the apparatus performer executes most of his movements about or around the shoulder girdle. The lighter the lower part of the body, the more easily the intricate movements on the horizontal bar, parallel bars, and the vaulting-box may be executed. The swimmer, who in shape and form resembles closely the all-round athlete, has a deep, broad, and strong chest, broad shoulders, normally developed hips, and a fine, soft, and elastic skin. 'The peculiar formation of the thorax resulting from swimming presents a triangle which is formed by the clavicles, the outer borders of the thoracic muscles and the ensiform cartilage of the sternum, which resembles a triangular plate called the "swimmer's plate".'

EPILOGUE

The foregoing surely make it clear how any definite progress in physical education will only be made if the scientific basis is given full recognition. The medical adviser, hitherto ignored by most physical training centres, must be admitted to a very full participation in the planning as well as the practising of sports, games, and exercises. He will have to be a researcher as well as a general practitioner. Physical, physiological, and psychological standards are now available for testing the value of the various cults and systems of physical training, and they must be used both for this purpose and for individual pupils. Trial must replace guessing as to probable values, and there is a great future for statistical work also, so long as the criteria of scientific statistical work are fully observed; many statistics published so far fail lamentably in this respect.

At present the national cry appears to be *panem et circenses*; it foreshadowed the fall of the Roman Empire when first uttered as a national objective. If history is not to repeat itself thus deplorably, science must translate this cry into a practical progress on sound lines towards the noblest conceivable ideals, for then the latent mischief in such a demand will be rooted out. If the new National College is to succeed in improving the health of the whole community it must take note of the poorest as well as the richest, whether such a comparison relates to opportunities of health physical development and recreation or to the physiological and psychological needs of all members of the community. Blind leaders of the blind must be deposed from their power to lead the nation astray any longer. The light of knowledge must be made available to all, so that all may be enabled to learn how to express to the uttermost in each case their latent capabilities for enjoying life, for increasing strength, and for adjusting themselves rightly to the world.

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